

Simple Propositions

AVERY

IP7019551

From GE

**Specification and Scope of Work
Last Stage Buckets**

BACKGROUND.

A proposal is requested for the supply and installation of new Last Stage Buckets (LSB's), on the _____ Low Pressure Turbine Rotor. The Unit # _____ Turbine Generator is a GE S-2 model. The LSB's are GE 30", self shielded buckets.

PROPOSAL REQUIREMENTS

- Vendor shall provide a total turn-key project to replace six rows of LSBs and shall include, but not limited to, all NDT prep, NDT, LSB buckets, low speed balancing, and all preliminary dynamic and static analysis.
- The proposal for the replacement LSB's shall be for fabrication from Jethete M-152 material, with hardness of 330 to 350 BN, incorporating a weld-attached stellited nose bar.
- The buckets shall also include larger nub and rocker sleeve, over-twist design with larger tenon hole clearance and larger associated tenon and cover piece.
- The design shall be similar to the Mark IV version, available from GE in the early 1970's.
- Buckets shall be certified and all confirmation of all quality inspections and/or reports to be provided with delivery of buckets.
- Vendor shall describe design criteria and program of analyses, test and operating experience which will be or has been performed to assure the design criteria are met for the _____, Unit _____ turbine generator, for torsional and lateral natural frequencies with the new LSBs installed.
- The proposal shall include a complete description of the welding procedure for attaching stellite nose bar to bucket, including nose bar geometry.
- The proposal shall identify costs for replacement dovetail pins. The nominal inner dovetail pinholes are approximately 0.XXX" diameter, the center dovetail pinholes are approximately 0.XX" diameter, and the outer dovetail pinholes are approximately 0.XXX" diameter. All dovetail pins are XX" in length and fabricated from H-11 tool steel.
- Proposal shall include design information of condenser backpressure alarm and trip points, including operation allowances as a function of condenser backpressure.
- Proposal shall include a schedule showing time frame and major milestones for the installation of the last stage buckets.
- Any modification to other turbine components, such as diaphragms, seals, flow guides, etc., may be included as an addendum only. Reasons and value for all modifications shall be explained in the addendum.
- Proposal shall also include the number of existing installations with corresponding years of service of the proposed bucket design.
- Proposal shall include warranty information related to material and workmanship.

SCHEDULE

*dovetail
pin map*

*torsional frequencies
lateral frequencies*

Bidders shall also provide a proposal for installation of LSB's during a scheduled XX-day outage during the months of _____ through _____, 20__.

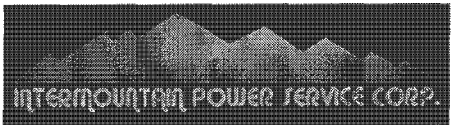
- The turbine overhaul contractor shall perform all NDT testing of the rotor bore and LSB dovetails, including preparatory work required by the applicable codes and standards. Vendor shall list all applicable NDT codes and standards as part of their proposal and submit a report including data and recommendations after all work is complete.
- Remove the existing buckets and then install new buckets provided as part of this contract. Afterwards the vendor shall complete a low speed balance on the final assembled rotor.
- It is anticipated that the rotor will be available to successful vendor on _____, 20__ and LSB installation, including low speed balance, shall be completed by _____, 20__.
- Schedule shall be coordinated and finalized with successful bidder, turbine overhaul contractor and _____ by _____ 20__.

Proposed Bucket Design Data
(To be completed by Bidder)
Last Stage Buckets

Manufacturer	
Bucket model name	
Effective length	
Weight per bucket (lb)	
Type of erosion protection	
Method of erosion shield attachment (if applicable)	
Material	
Cover type	
Mid-span support type	
Backpressure alarm	
Backpressure limit (trip)	
Number of rows installed	
Oldest installation using proposed bucket design	
Experience List	(Comprehensive list of all projects for parts and service using proposed buckets)

Low Speed Balance Acceptance Criteria	
Low Speed Balance Plan	
Torsional Frequency Analysis Criteria and Results	
Lateral Frequency Analysis Criteria and Results	

From Turbine



RFP for Last Stage Blades for IPP LP Rotors

This request is to provide last stage blades for _____. This unit is a GE S2 design with a nominal rating of 820 MW, Serial number _____ with a commercial operation date of _____. The existing blades are originally designed 30" LSB of the continuously coupled tie wire sleeves type. They are manufactured out of a GE type Jethete material and are a self shielded design.

The blades presently in the unit have seen a significant amount of erosion. *See attached photos.* The proposed design should maintain original steam path design, reduce erosion rates, and prolong the life of the blades.

Proposal is due on _____ and the following specifications must be presented in the tables below:

- Design details of the proposed blades including:
 - Mechanical material properties of the blades (primarily tensile strength, hardness and fatigue strength) both of the parent material as well as any shielding
 - Blade shielding type including details on the method of attachment
 - A finite element analysis showing the steady stress analysis of all key features of the blades (cover, tenon, tie-wire, air foil, root, disk attachment) with a summary of the stresses in a format similar to below

Summary of Calculated Steady Stresses (Required)

Structural Feature Material Yield Strength:	Max Equivalent Elastic Stress		Max Principal Elastic Stress		Local Yielding?*	True Stress	
	ksi	MPa	ksi	MPa	Yes or No	ksi	MPa
Tip Linkage							
Tie Wire – Lashing Lug							
Airfoil							
Blade Root							
Pins							
Disk Attachment							
* Yes is indicated if the reported elastic stress exceeds the material yield strength.							

- A dynamic analysis of the blade disk frequencies and dynamic stresses both at zero and rated speeds for the first 10 modes, summarized in tabular form similar to below

Blade-Disk Natural Frequencies, for both zero speed and 3600 RPM (Required)

	Frequencies Shown are: __ Calculated __ Measured			
<i>Nodal</i>	<i>Mode Family</i>			
<i>Diameter</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>

Resonant Dynamic Stress (Maximum Principal) for ND Mode Families (Required)

Region	Mode A		Mode B		Mode C		Mode D	
	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
Tip Linkage								
Tie Wire – Lashing Lug								
Airfoil								
Blade Root								
Pins								
Disk Attachment								

- The blades should be moment weighted and the documentation provided

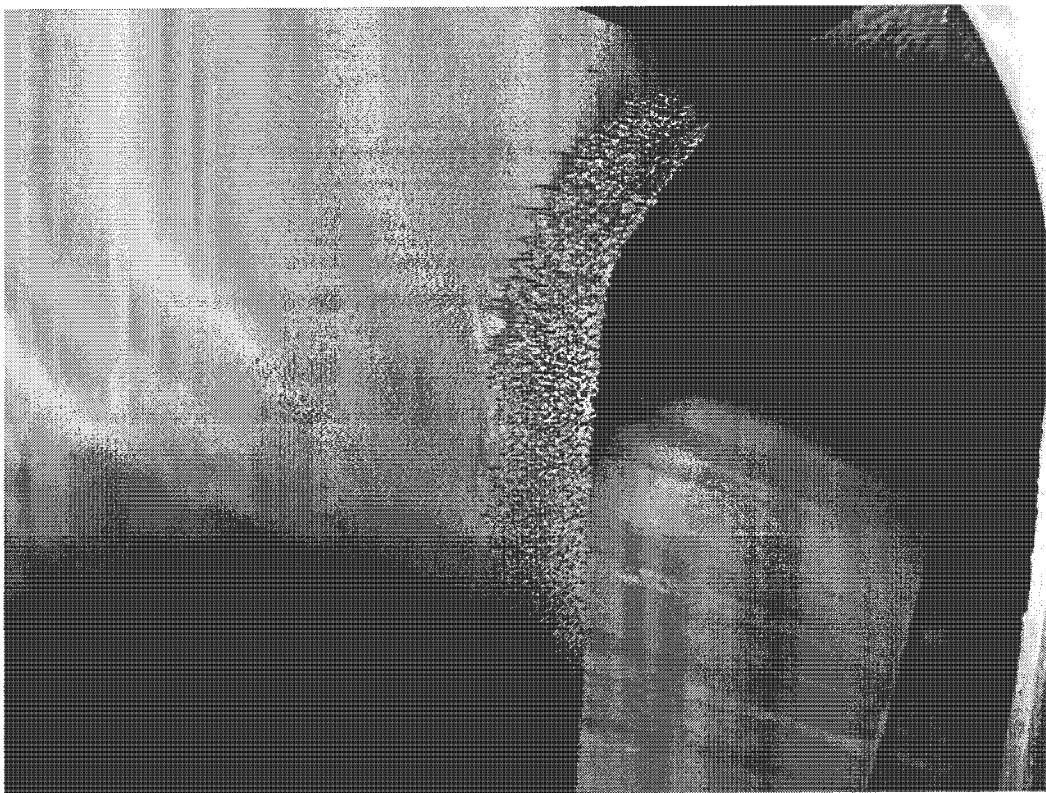
The proposal should provide the following options / information:

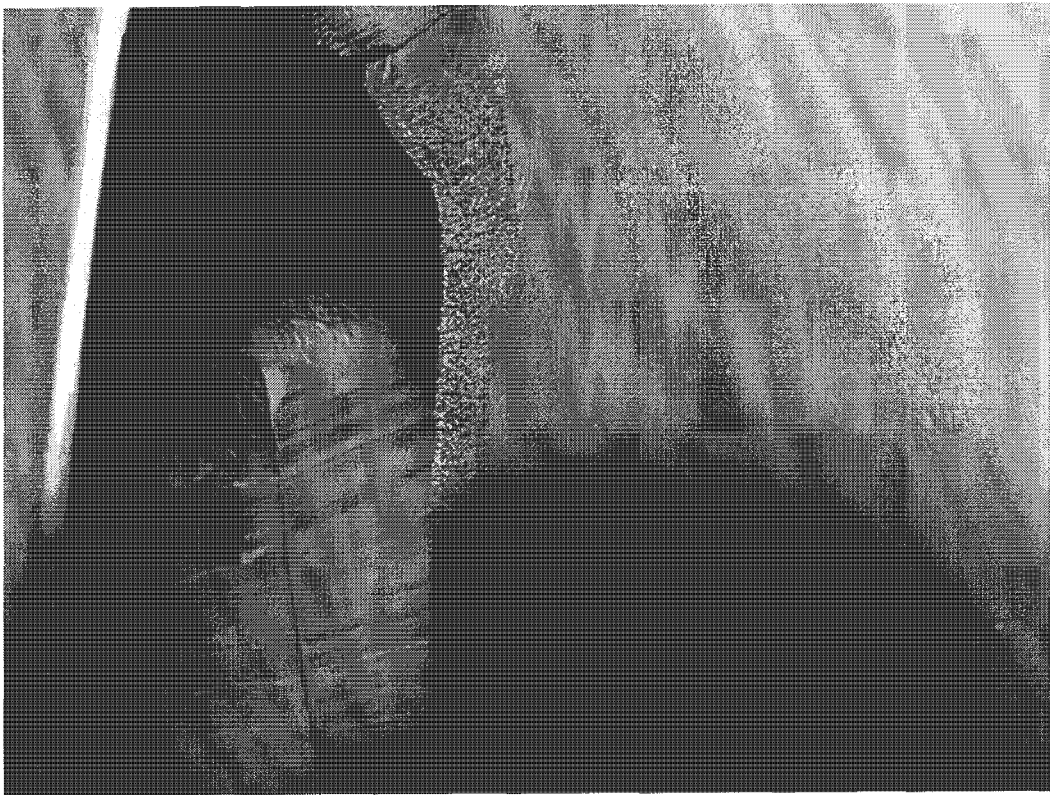
- Cost of blades on a per row basis, 6 rows each on Unit-1 & 2. Include options in cost per row basis: self shielded, braised-on Stellite shielded, and electron beam welded (EBW) Stellite shielded.
- Cost of hardware on a per row basis.
- Cost to install on a per row basis.
- Cost to perform a low speed balance performed on site.
- Proof of ISO-9001/2000 certification for blade manufacturing.
- Proof of possession of all raw materials for blades is in vendor's stock at time of award.
- Delivery options:
 - Total time to obtain forgings.
 - Time required to machine.
 - Time required for installation once rotor is removed from machine.
 - Vendor must prove the ability to install own blade design.
 - Vender must have the ability to install blades on site, with a proven record of doing such.

After review of proposals, a follow-up meeting may be held to discuss in detail any technical aspects of the design which needs to be clarified. IPP expects to review the finite element stress analysis (FEA) and reserves the right to obtain a third party in depth review of the FEA.

Technical questions should be directed to:

Dave Spence
Technical Specifications Director
435-864-6449





From Leo Molera - MDA

SPECIFICATION # XXXXXX

**Rev 0
Month, Year**

**LOW PRESSURE STEAM
TURBINE LAST STAGE RETROFIT FOR
IMPROVED EFFICIENCY**

Station Name UNIT # XX

Table of Contents

Section	Page
1.0 Introduction	1
2.0 Facility Location	1
3.0 Turbine Description	2
4.0 Scope of Work	3
5.0 Codes and Standards	4
6.0 Definitions	4
7.0 Technical Requirements	5
8.0 Schedule	8
9.0 Installation	9
10.0 Documentation	10
11.0 Shipment and Delivery	11
12.0 Spare Parts	12
13.0 Warranty	12
14.0 Correspondence	12
15.0 Attachments	13

- Attachment A- Turbine Maintenance Histories
- Attachment B - Modified Turbine Tests for Each {Station Name} Unit
- Attachment C. Plant Heat Balances

1.0 INTRODUCTION

This specification provides project specific requirements for low pressure steam turbine 30 " last stage buckets designed to provide improved reliability and efficiency on {Quantity} (X) units (Units X and Y) at the {Station Name} Power Station. Last Stage Blades on the A, B, and C low pressure steam turbines will be replaced.

The low pressure turbine last stage turbine projects shall incorporate the latest technologies to deliver the maximum reliability and efficiency at the present rated gross output and within the existing outer shell configuration.

The intent of this modification is to maximize efficiency without increasing plant MW output while incorporating component reliability with the latest advances in steam turbine technology.

The Contractor shall provide a complete scope of work to design, manufacture, install, {Customer Name} will use its in house labor force to perform turbine disassembly and reassembly activities.

It is not the intent of this specification to provide all details necessary to provide a complete scope of work.

This specification should be used in conjunction with Specification XXXX, "General Conditions", revised {Month, Date, Year}, and other {Customer Name} contractual agreements (Contract Documents) to provide requirements related to this project.

Packaged pricing is requested for the first unit to be modified {Station Name} Unit #X in April, 2010 as well as for Unit X in April, 2011.

2.0 FACILITY LOCATION

The {Station Name} Power Station (the plant) is a {Quantity} (X) unit, fossil-fired, power generating facility owned and operated by {Customer Name}. This facility is located on {Address}, {Station Name}, {State, Zip Code}. The phone number to the main office is {Phone Number}. The plant manager is Mr. {Plant Manager}.

3.0 TURBINE DISCRIPTIONS

The {Quantity} (X) units at {Station Name} have General Electric manufactured steam turbines of the S-2 design. These turbines are tandem-compound reheat units with three double-flow low-pressure sections.

The units are currently overhauled every {Quantity} (X) years. The overhaul interval will be extended to {Quantity} (X) years. The maintenance history for each unit is provided in Attachment A. More detailed maintenance records are available for review at the plant.

The most recent modified turbine test for each unit is provided in Attachment B. Additional turbine test information is available upon request.

The design data of each unit is provided below:

3.1 Unit X Design Data

Serial Number:	XXXXXX
Speed:	3600 RPM
Last Stage Bucket (LSB) Length	30 inch
In Service Date:	Month, Year

3.2 Unit 4 Design Data

Serial Number:	XXXXXX
Speed:	3600 RPM
Last Stage Bucket Length	30 inch
In Service Date:	Month, Year

Original plant heat balances are provided in Attachment C.

The A, B and C Low Pressure Turbine sections (turbine and generator ends) of Units X and Y currently have GE LP 30" last stage (L-0) buckets.

Units X and Y will be modified with continuously coupled blades which incorporate the latest advances in steam turbine technology.

4.0 SCOPE OF WORK

The work shall comply with all requirements of the specification(s) and incorporate the highest quality of design and workmanship. A complete scope of work shall be provided including all engineering, design, manufacturing, shipment, and installation, services, tooling,. The scope of work shall properly address all interfaces with existing plant components. It is not the intent of this specification to specify all details and services necessary to provide a complete scope of work.

{Customer Name} Maintenance Service Department (MSD) will supply the labor required for the turbine disassembly and reassembly.

The engineering, design and manufacturing scope shall include all shop and field inspections and measurements, development of new exhaust loss curves, compliance with applicable codes and standards, disposition of non-conformances, quality control, and documentation thereof. The installation scope shall include shop supervision, installation drawings and procedures, machining, tooling, hardware, and all modifications to existing components to properly accommodate the turbine bucket replacement.

The scope of work for each unit bucket replacement shall include, but is not limited to:

- 4.1 New last stage buckets for the A, B, and C low pressure turbines.
- 4.2 Updated turbine back pressure limit curve for the Last Stage Blade.
- 4.3 Thermal kit revision- exhaust loss curve for Last Stage Blade.
- 4.4 A warranty valid for a minimum of 1 year following the completion of the performance test.
- 4.5 If the Contractor is performing the installation in its shop, transportation of the rotors to the Contractor shop and the return of the rotors to the {Station Name} Power Station site.

5.0 CODES AND STANDARDS

Equipment covered in this specification shall comply with all currently approved applicable industry codes and standards, and all federal, state, and local safety and health requirements. The codes and standards shall include but not be limited to:

<u>Short Term as Used Herein</u>	<u>Complete Identification of the Sponsor Organization</u>
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society of Testing Materials
AWS	American Welding Society
OSHA	Occupational Safety and Health Administration

If there is or seems to be a conflict between the specification(s) and a referenced document, the matter shall be referred to the {Customer Name} Engineer, who will clarify the matter(s).

Any non-US codes or standards that apply to components supplied under this specification shall be identified in the proposal.

6.0 **DEFINITIONS**

Engineer - The preparer of the Specification and the responsible party for all the requirements of and any changes necessary to the specification(s).

Company - This term shall refer to the equipment or material Purchaser, Customer and Owner which is {Customer Name} also referred to as {Customer Name}.

Contractor - Shall refer to a company submitting a proposal to fulfill the requirements of the specification(s) or the successful company who is awarded the contract and/or purchase order and who has accepted the overall responsibility for fulfilling the requirements of the specification(s). This term shall include any subcontractors that the Contractor may use.

Maintenance Service Department (MSD) – The {Customer Name} in house construction and maintenance organization that will be performing turbine retrofit activities.

7.0 TECHNICAL REQUIREMENTS

7.1 Design and Installation

The contractor shall incorporate the following requirements in the design of the new last stage buckets and new diaphragms (if required):

- a. A high efficiency aerodynamic design
- b. A material and vane design that provides superior protection against erosion.
- c. A high structural integrity during normal operation and abnormal over speed conditions.
- d. Protection against stress corrosion cracking and corrosion fatigue
- e. Protective design features to guard against flow-excited vibration, flutter and fatigue.
- f. Buckets covers are to have coupled construction and provide superior tip leakage control.
- g. A maintenance interval of ten (10) years.

7.2 Manufacturing

The entire material procurement and manufacturing process shall be subject to a stringent quality control program. Upon Contract award, the Supplier will provide a Quality Inspection and Test Plan (QST) to the customer. This document will outline the QC operations, identify potential witness points, and denote the documentation that will be provided to the customer for record purposes. The customer will review and approve the QST with any agreed upon modifications. Two copies of all material certifications and test reports, as agreed to in the QST document, shall be supplied to the customer as soon as they are available, and or applicable.

Access to the Contractor's manufacturing facilities, offices, and personnel shall be provided to {Customer Name} representatives, or their agents, for the review of work in progress, testing, quality control, or manufacturing. For agreed upon witness points, the Contractor shall notify at least 15 working days prior to any testing, so that {Customer Name} may witness the testing.

Nondestructive testing procedures shall be submitted to {Customer Name} for review and approval. The contractor will provide its NDE procedures and associated qualifications and certifications for NDE personnel for review and approval by a {Customer Name} (Level 3 inspector). Baseline NDE inspection reports will be provided to {Customer Name} as soon as possible and within thirty (30) of the inspection date.

7.2.1 Balancing and Overspeed Tests

The rotors are to be low speed balanced tested. Certified documentation of such test results shall be forwarded to the {Customer Name} engineer upon completion. Contractor shall provide a sufficient assortment of balance weights should field balancing be required during startup.

7.3 TESTING

Visual Inspection

Visual inspections shall be conducted throughout the manufacturing and Installation processes to maintain proper quality control standards.

Radiographic Inspection

All documentation data including final acceptance films for all radiographs shall be made available for review and acceptance by the Company prior to release for shipment of the inspected components.

Manufacturing Standards, Inspections & Tests

Components shall be manufactured from materials made using state of the art melting, refining, heat treatment and manufacturing processes. The nondestructive testing, mechanical testing, quality control procedures, and quality assurance programs applicable to these components shall assure that they are of high quality and suitable for long term reliable service. Certified material test reports and certified reports of the results of additional tests such as impact tests shall be provided for the components, as applicable.

The Contractor shall identify the following information for each component with their proposal:

- The standard specification and material grade/class applicable
- The heat treatment, mechanical, and nondestructive requirements , as applicable, for standard materials supplied
- For components manufactured from proprietary materials identify the material composition, heat treatments, mechanical properties and testing, nondestructive testing, stability testing, and identification marking requirements specified by the manufacturer
- Weld repair limitations and process and inspection requirements if weld repair is permitted
- Material suppliers and country of origin
- Certified material test reports to be provided

8.0 SCHEDULE

8.1 Milestone Dates

The first turbine bucket replacement is tentatively scheduled for installation in Unit X beginning April, 2010. . Unit Y will be installed in April, 2011. Exact schedule dates will be determined later.

Delivery Dates

Delivery of all turbine components is required to meet the outage schedule.

Award of Contract

All proposals must be submitted within {Quantity} weeks of the RFP issue date. The date for the award of the contract for the turbines is expected within {Quantity} weeks from the receipt of proposals.

Payment Schedule

The Contractor's bid should propose a payment schedule showing release dates for engineering, material procurement, etc. The contract award date should coincide with the engineering release payment. In addition to the payment schedule, a cancellation charge schedule shall be provided that would show the costs if the project is canceled.

Design/Manufacturing Schedule

Within one (1) month of award of the purchase order, the Supplier shall provide a detailed design and manufacturing schedule. The schedule will contain sufficient detail to track monthly progress and provide dates for various testing and inspection. The schedule will include engineering activities and potential witness points. It will also show the remaining float for each activity. Monthly updates will be required.

Approval Drawings

Customer shall have the opportunity to view all drawings during mutually agreed upon meetings.

9.0 INSTALLATION

The Contractor shall provide supervision, engineering, tooling, specialized machining and services necessary to perform the following scope of work:

- 1.0 Shipment of the A, B, and C rotors from {Station Name} loading bay to the Contractor shop and the return trip (if required).
- 2.0 Dimensional checks of the rotor
- 3.0 Removal of the existing last stage buckets pins and buckets including any necessary drilling of pins
- 4.0 Preparation, cleaning, and NDE of bucket wheel dovetails
- 5.0 Inventory of new turbine components
- 6.0 Installation of new last stage buckets, pins, and covers
- 7.0 Specialized clearance machining
- 8.0 Low speed balancing

*on site
no shipping*

The Company will use its in-house MSD labor for onsite turbine disassembly and reassembly.

9.2 Company Responsibilities

{Customer Name} will supply the required labor for the turbine disassembly and reassembly.

10.0 DOCUMENTATION

10.1 Fabrication Schedule

The Contractor shall prepare and submit a fabrication schedule showing estimated dates for turbine bucket rows:

1. Start of procurement activity
2. Start of fabrication
3. Manufacturer's inspection points
4. Major production milestones
5. Completion of fabrication

10.2 Documentation Required for Delivery

10.2.1 Approved QC Documentation List

A copy of the appropriate Company QC Documentation List shall be included with each documentation package delivered. During preparation for final documentation and shipment, the Vendor will compile the documentation package and indicate the quantity of each type record.

All required documentation should be furnished upon, or prior to, the arrival of the hardware at the site. If requested, the Certificate of Compliance accompanying the shipment will be accepted with the required documentation package to follow within ten days. Final acceptance of the equipment will not occur before the complete documentation package is received.

11.0 SHIPMENT AND DELIVERY

Materials manufactured for this specification are to be stored indoors until ready for shipment. If there is a possibility for temporary outdoor storage of any components they shall be packaged to protect them from corrosion damage.

All turbine components shall be properly supported and weatherized to prevent damage from occurring during loading and shipment. All damage incurred during loading and shipment shall be repaired by the Contractor at his expense. The Contractor shall be responsible for shipment of all turbine bucket components. It will be the Supplier's responsibility to deliver all components into the shop bay, under the crane hook, where they can be immediately lifted with no extra work required.

All turbine components shall be delivered to the site at least {Quantity} (X) weeks prior to the outage start date for inspection.

The lifting weight and center of gravity shall be prominently marked on all delivered components.

12.0 SPARE PARTS**13.0 WARRANTY**

The Contractor shall warrant that the equipment described in this specification and all its parts shall be free from defects in material, design, and workmanship. This warranty shall extend for a minimum of twelve (12) months after commercial operation and shall be extended for another year if failure of equipment parts requires replacement or repair. Replacements or repairs within this period shall be at Contractor's expense.

14.0 CORRESPONDENCE

All correspondence including schedules, drawing transmittals, inspections, procedures, plans, submittal letters, etc. shall be submitted to the {Customer Name} {Group Name}., , Attention: Mr. {Name},{Address}..

Contractual correspondence relative to prices, terms, conditions, price adjustments and other commercial matters shall be addressed and submitted to the {Customer Name} {Group Name}., , Attention: Mr. {Name},{Address}. All correspondence shall reference the Company Purchase Order Number and the Contractors Job Order Number.

15.0 ATTACHMENTS

- A- Turbine Maintenance Histories
- B- Modified Turbine Tests
- C- Plant Heat Balances

EPRI Procurement
Guidelines

1

STEAM TURBINE BLADE/BUCKET PROCUREMENT GUIDELINES

This section provides a general guideline of the technical requirements recommended to guide the purchase of fossil plant steam turbine buckets. As part of the procedure, a list of requirements is recommended in association with any reverse engineering or engineering analysis that is performed and for any manufacturing drawings that are supplied along with the procured components. Documentation associated with the manufacturing and quality control checks made of the delivered components is also specified to ensure that the final product complies with the requirements identified in the engineering procedure.

The procedure itself is designed to be generic in nature and to account for different possible procurement scenarios. The engineer responsible for any procurement of buckets/blades is expected to tailor this procedure according to the situation or the type of supplier that is solicited to provide a bid. An example of such a bid package to obtain a row of blades/buckets is provided in Appendix A. For example, if the buckets/blades are to be procured through a third-party supplier, the requirements associated with the reverse engineering and engineering analysis within this procedure should be included. The requirements associated with the process of reverse engineering are designed to ensure that the dimensions used to prescribe manufacturing tolerances are taken from enough samples to sufficiently represent those used in the original.

General Requirements associated with the engineering analysis are specified to provide critical information on **frequencies**, **operating stresses**, and **fatigue life**. **Subrequirements** specify further actions that should be undertaken to check locations where the predicted stress exceeds the general requirement.

As shown in Figure 1-1, stresses are required at key locations in the design to indicate whether they are expected to approach or exceed the yield strength of the material (and therefore may be susceptible to low cycle fatigue [LCF]) or the endurance limit of the material (high cycle fatigue [HCF]). Frequencies for the first four fundamental modes are requested in order to show the margin of tuning and the margin from resonance that the assembled row can be expected to achieve. Tables are attached to assist potential suppliers in identifying the information that is requested under each separate requirement. Having the potential suppliers tabulate their responses in this manner makes it clear what level of detail is being requested and ensures the results are supplied in a consistent format.

Steam Turbine Blade/Bucket Procurement Guidelines

It is recommended that third-party suppliers should be asked to comply with all of the basic requirements of this procedure. It is also desirable that original equipment suppliers (OEMs) comply with this procedure, although this may be subject to some negotiation. However, if an original design has been modified to improve stage efficiency or correct a reliability problem, a structural analysis of the new design should then be specified as a requirement, even from an OEM.

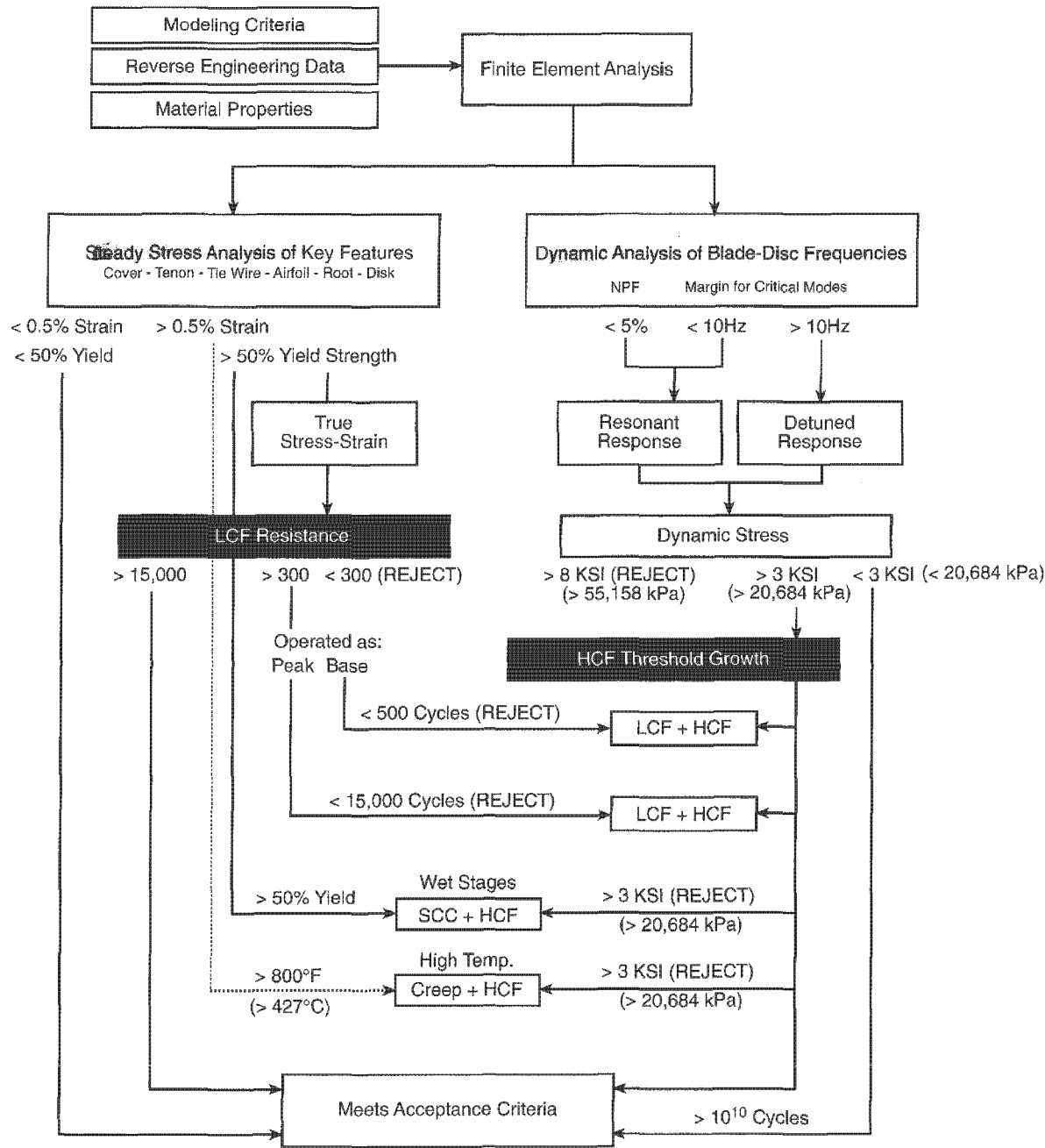


Figure 1-1
Design Audit Procedures and Recommended Acceptance Criteria

Steam Turbine Blade/Bucket Procurement Guidelines

Nomenclature used throughout this procedure referring to different structural features of a bucket is identified in Section 1.9 and illustrated in Figure 1-2.

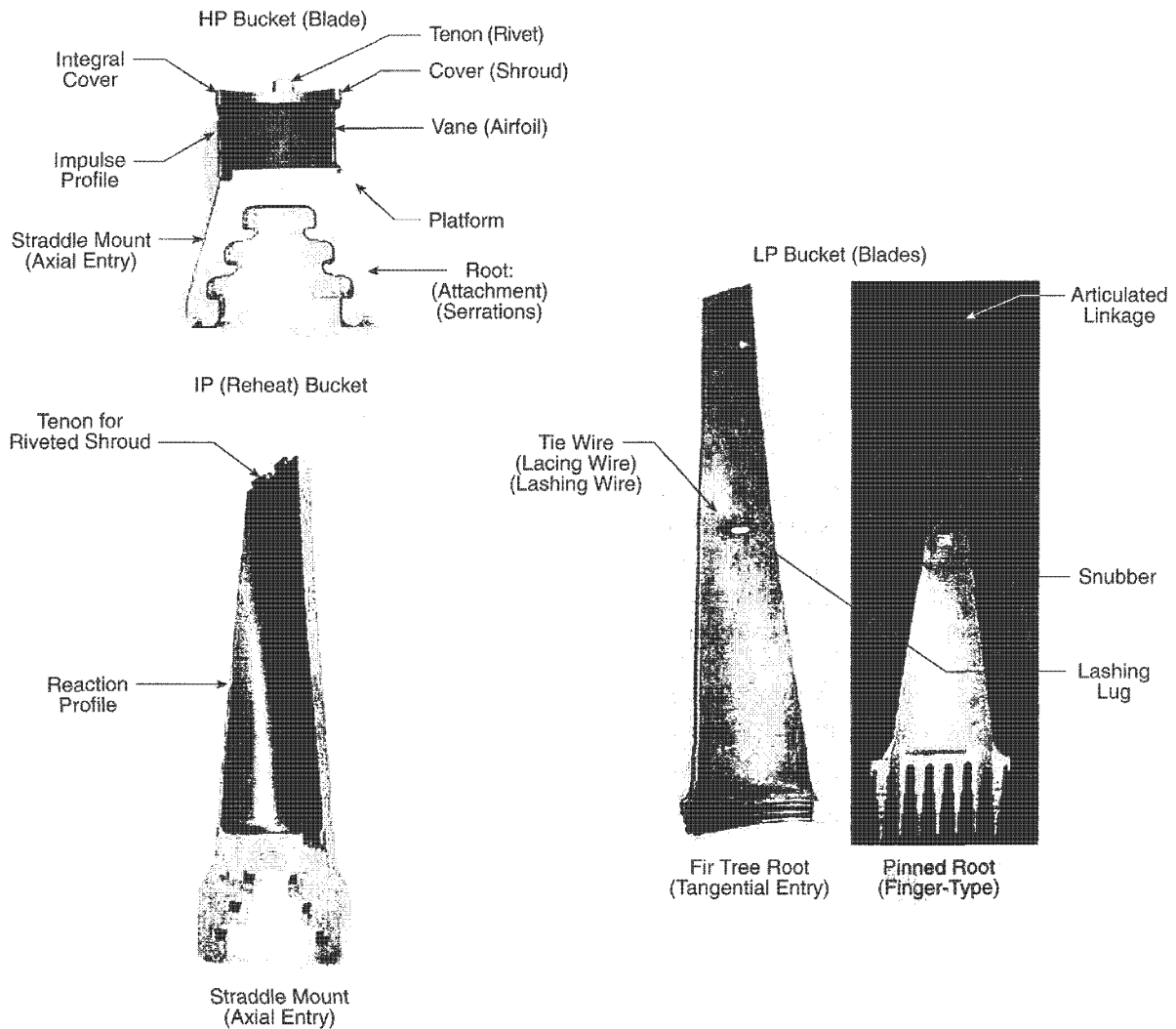


Figure 1-2
Blade/Bucket Nomenclature Identification

The following list contains requirements for blade/bucket suppliers:

1. This procedure defines a list of technical requirements for the supply of a row of steam turbine buckets. The acceptance requirements prescribed within this procedure are to become part of a warranty on the new components.
2. The procedure includes the completion of the tables that define features of the supplier's product. The details supplied in response to this procedure should form the basis for accepting the final delivery of the components, if the supplier is awarded the contract.

Steam Turbine Blade/Bucket Procurement Guidelines

3. The replacement buckets should (a) be completely compatible with the present turbine steam path components, (b) result in no detrimental changes when compared against the unit operation with the present components, and (c) place no serious limitations on the operation, maintenance, or safety requirements of the plant.
4. Any modifications to existing rotors, stationary parts, bearings, etc. to achieve item 3 should be identified and included in the overall proposed cost.
5. Any unplanned modification or work required at the installation of the blades due to design or manufacturing error will be at the supplier's expense.
6. If the components supplied under this procurement procedure are to be obtained by reverse engineering of specimens, then all analysis, models, and drawings used to produce the blades will be supplied with the parts in accordance with the requirements set forth within this procedure.
7. If the blades supplied under this procurement procedure are of an original design, then the manufacturer will agree to provide, upon receipt of a letter of intent to purchase, sufficient details to allow independent finite element (FE) modeling and analysis of the modified design by the purchaser or a qualified third-party consultant. Exchange and/or use of any proprietary information required to complete the independent analysis will be conducted under mutually accepted conditions of confidentiality.
8. Upon selection of a final supplier, a letter of intent to purchase will be issued based on the response to the information requested within this procurement procedure.

1.1 Reverse Engineering

1.1.1 General Requirement: Geometry and Dimensions

- If the geometry and dimensions of the components are to be reverse engineered from an original design, measure a minimum of 10 blade samples to establish the design parameters from a range of measured tolerances. Average all dimensions obtained from the 10 samples. Reflect this average on final machining and manufacturing drawings.
- Table 1-1 represents a minimum of information to report in order to document how key dimensions and tolerances were established. Supply the final parameters to the purchaser for review and approval before manufacturing commences.
- Identify by type and manufacturer the coordinate measurement system and any tools applied to reverse engineer dimensions from the samples. All devices used to reverse engineer dimensions from original samples must perform measurements with an accuracy of 0.002" (0.0508 mm).

1.1.2 General Requirement: Structural Features

1. As a minimum, measure design features of the bucket in accordance with the criteria identified in Subrequirements 1.1.2.1 through 1.1.2.5.
2. For longer blades, measure the moment weight of individual blades, and make a determination of the most appropriate distribution of the blades around the rotor rim to minimize the total "out of balance" forces that need to be balanced. Provide moment weight data in the form of a drawing or other method and deliver it as part of the blade supply. Measured blade weight must be accurate to the nearest 0.01 lb.-in. (115.21 g-mm).

1.1.2.1 Subrequirement: Tenons

1. Determine dimensions describing any tenon from the coordinates measured from no less than three points taken along each straight or curved line segment that makes up the overall geometry.
2. A fillet radius is required where the tenon joins the main profile in which no discontinuities or surface tears will be acceptable.
3. Sufficient material to form the tenon head should be available to be certain that the cover band will be fastened tight to the tip platform resulting in gaps under the cover band that do not exceed 0.005" (0.127 mm) on the inlet edge or 0.003" (0.0762 mm) on the discharge side.
4. The tenon head (after peening) should have no steps or indentations on its surface.

1.1.2.2 Subrequirement: Cover

1. Determine dimensions describing any cover from the coordinates measured from no less than three points taken along each straight or curved line segment that makes up the overall geometry.
2. Chamfer the underside of band holes. When circular tenons are used, the underside of the band holes must be chamfered or have a radius sufficient to prevent interference between the tenon and the underside of the cover band fillet radius or chamfer.
3. Cover bands are to have chamfers on both the inner and outer edge of the tenon hole. Remove any burrs from this chamfer.
4. The inner chamfer of the tenon hole must be sufficiently large enough to prevent interference between the cover and tenon fillet radius.

*Steam Turbine Blade/Bucket Procurement Guidelines***1.1.2.3 Subrequirement: Tie Wire/Lashing Lug**

1. Measure dimensions used to describe any lashing lug or device used to tie blades together in no less than 0.001" (0.0254 mm) increments.
2. For non-circular lugs, obtain cross-sectional measurements at no less than six locations to represent the geometry.
3. Where floating tie wires are used, drill the position of the vane hole relative to the root to ensure correct alignment.
4. Chamfer or round off all hole corners in accordance with the original design form.
5. If the wire is brazed to the blade vane, control the quantity of material in accordance with the original design form.
6. After brazing, remove excess braze material from the wire and vane. Clean the area around the braze joint with an emery cloth after fusion is complete.
7. If welding is used to attach or connect stubs, apply pre- and post-weld heat treatment in accordance with the original design heating and cooling rates.

1.1.2.4 Subrequirement: Airfoil

1. Obtain coordinates for a minimum of three cross-section profiles or at every 3.0" (7.62 cm) increment along the entire airfoil height (that is, from platform to cover) for each of the 10 samples.
2. For each of these individual cross sections, measure a minimum of 200 points to fully describe the entire circumference of the profile.
3. Out of these 200 total points, use no less than 30 points to describe the shape of either the leading edge or the trailing edge radius of the profile.
4. As a minimum requirement, measure the fillet radii at the platform (where the airfoil joins the platform) at 1.0" (2.54 cm) intervals on both the concave and the convex sides.
5. Take a minimum of three fillet radii measurements at both the leading edge and the trailing edge.
6. Apply the same requirements to establish the fillets of an integral cover.
7. Allow only a plus tolerance in discharge tail thickness to ensure against local thinning.

1.1.2.5 Subrequirement: Root Attachment

1. Take dimensional coordinates on a cross-section profile that is normal to the direction of the root serrations. Nomenclature is identified in Figure 1-3.
2. Use a minimum of five points to describe any curved or straight segment along the entire circumference of the cross-section profile.
3. For a straddle-mount/tangential-entry root, define any curvature by five data points taken along each hook, measured in the tangential direction [1].

1.1.3 Administrative Requirements

The vendor, supplier, or OEM should provide the information in Table 1-1 to the designated utility representative.

Table 1-1
Record of Basic Dimensions from Samples

Number Samples	Minimum 10 Samples To Be Measured									
Accuracy of System Used:	Accuracy to 0.002" (0.0508 mm) Specified									
Measurement System Used:	Model and Type of Commercial System:									
Locations	Sample Numbers 1 Through 10									
Total Blade Height										
Maximum Blade Width										
Filet at Blade Platform										
Cover Thickness										
Cover Width										
Cover Length										
Chamfer (Inner/Outer Edge)										
Tenon Width										
Tenon Length										
Tenon Height										
Tenon Fillet Radius										
Inlet Nose Radius at Height 1										
Profile Chord at Height 1										
Profile Thickness at Height 1										
Discharge Tail Thickness at Height 1										
Inlet Nose Radius at Height 2										
Profile Chord at Height 2										
Profile Thickness at Height 2										
Discharge Tail Thickness at Height 2										
Inlet Nose Radius at Height 3										
Profile Chord at Height 3										
Profile Thickness at Height 3										
Discharge Tail Thickness at Height 3										

Table 1-1 (cont.)
Record of Basic Dimensions from Samples

Number Samples	Minimum 10 Samples To Be Measured									
Accuracy of System Used:	Accuracy to 0.002" (0.0508 mm) Specified									
Measurement System Used:	Model and Type of Commercial System:									
Locations	Sample Numbers 1 Through 10									
Total Root Width										
Width – Between 1 st Hook Pair										
Width - Load Bearing 1 st Pair										
Radius – Above 1 st Pair										
Spread – Between 1 st and 2 nd										
Width – Between 2 nd Hook Pair										
Width -Load Bearing 2 nd Pair										
Radius – Above 2 nd Pair										
Spread – Between 2 nd and 3 rd pair										
Width – Between 3 rd Hook Pair										
Width -Load Bearing 3 rd Pair										
Radius – Above 3 rd Pair										

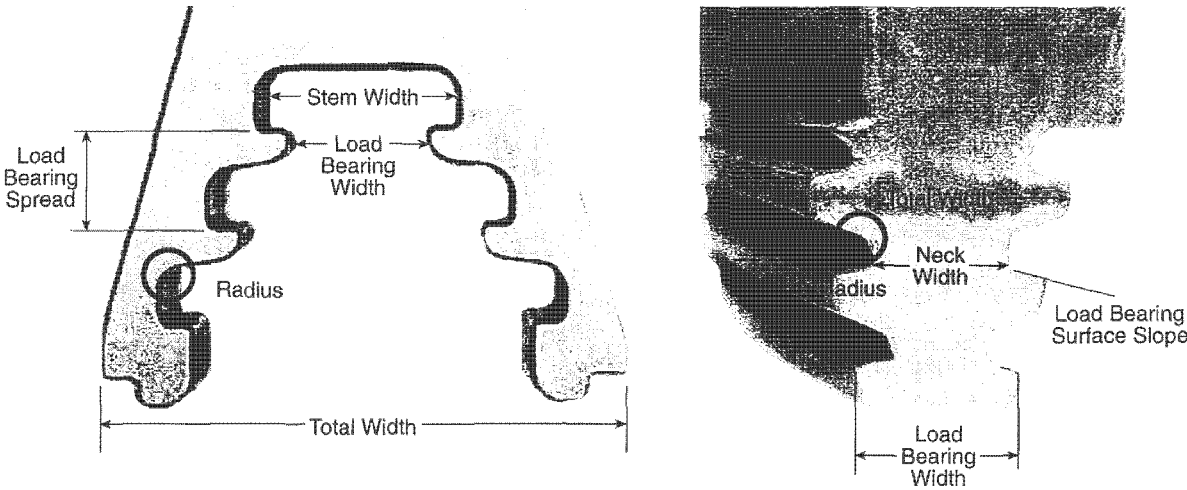


Figure 1-3
Nomenclature Used in Root Dimensional Measurements

1.2 Manufacturing Drawings

1.2.1 General Requirement: Drawings

1. Provide any manufacturing drawings that must be furnished with the buckets as AutoCAD or PRO-ENGINEERING files.
2. Prepare drawings in accordance with ANSI standards.
3. Drawings should identify all dimensions as specified in Section 1.1 and listed in Table 1-1.
4. Reflect a minimum ± 0.002 " (0.0508 mm) tolerance for all general dimensions, with the exceptions identified in Section 1.1.2 (General Requirements) and Sections 1.1.2.1 through 1.1.2.5 (Subrequirements).
5. Before manufacturing begins, provide for review and final approval any drawings to be furnished with the replacement buckets.

1.2.2 General Requirement: Detailed Information

1. Specify airfoil profiles by no less than 200 digitized points.
2. Any drawing of the root should specify tolerances for the load bearing lands and allowable clearances to the disc.
3. Where a notch blade is used, provide an assembly drawing along with allowable clearances.
4. Provide any platform pins with an allowable tolerance of interference.
5. Reflect procedures for any tang rolling on the final manufacturing drawings.

1.3 Tolerances and Surface Finishes

1.3.1 General Requirement: Tolerance Limits

1. Before components are shipped, individually measure them and check them to ensure their conformity to target tolerances identified against critical features of the design. Check and document buckets provided under this procedure using the format identified in Table 1-1.
2. The maximum allowable deviation from any general tolerances or coordinates identified on the manufacturing drawings is ± 0.002 " (0.0508 mm), except for the root attachment and integral cover shown in Table 1-2.
3. Indicate (on any milestone schedule supplied with a response to this procedure) the delivery of the tolerance check results.

Table 1-2
Allowable Tolerances [1]

Region	Target	Comment
Cover	± 0.002" (0.0508 mm)	For any given general dimensional target
Integral Cover	± 0.002"	Maximum allowable gap between interfacing surfaces
Blade/Bucket	± 0.002"	Target height for any given component
Profiles	± 0.005" (0.127 mm)	Chord/thickness at tip, mid-span, and platform
Platform	± 0.002"	Radii on concave and convex sides
Root	± 0.005"	Land to land, at all bearing surfaces
Surface Finish	32 μ-inches (0.8 micro-meter)	Root hooks and vane
Surface Finish	64 μ-inches (1.6 micro-meters)	All other surfaces

1.4 Materials and Properties

1.4.1 General Requirement: Allowable Materials

1. Report the generic blade/bucket material of the original design in Table 1-3.
2. The following materials are considered acceptable for the manufacture of low-pressure turbine buckets/blades:
 - AISI 403, AISI 410 with chemical and material properties as defined in ASTM 276-92.
 - AISI 630 (17-4PH), with chemical and material properties as defined in ASTM A705
 - Ti-6Al-4V
 - Jet Heat M152 (AMS 5719)
3. The following materials are considered acceptable for the manufacture of high-pressure turbine buckets/blades:
 - AISI 410
 - AISI 422
 - Carpenter H-46
4. The following materials will be considered acceptable for the manufacture of covers, tie wires, and pins:
 - Covers AISI 403, AISI 410, AISI 630 (17-4PH)
 - Tie Wires AISI 316, AISI 403, AISI 630 (17-4PH)
 - Pins AISI H11, A193, 316

Steam Turbine Blade/Bucket Procurement Guidelines

- 5. In addition to these basic materials, the supplier can elect to offer alternatives—if they are shown to offer superior or advantageous properties and performance. Report in Table 1-3 any materials to be used other than those listed above.
- 6. For any substitute materials indicated in Table 1-3, identify the chemical composition in weight percentages.

Table 1-3
Materials and Their Chemical Composition

ASTM Material Used in Bucket/Blade			
ASTM Material Used in Cover			
ASTM Material Used in Tie Wires/Lashing Lugs, Snubbers, etc.			
ASTM Material Used in Root Attachment Pins			
Indicate NA (Not Applicable) If Blades are Freestanding, Have Integral Covers, and/or Are Not Pinned.			
Chemical Composition	Bucket/Blade	Cover	Pins
Chromium (Cr)			
Molybdenum (Mb)			
Nickel (Ni)			
Cobalt (Co)			
Manganese (Mn)			
Carbon (C)			
Sulfur (S)			
Phosphorus (P)			
Silicon (S)			
Nitrogen (N)			
Titanium (Ti)			
Other			

1.4.2 General Requirement: Mechanical Properties

- 1. For each of the materials that are listed in Table 1-3, identify the tensile strength, yield strength, percentage of elongation, reduction of area, hardness, Charpy V-notch, fracture toughness, and threshold stress intensity using the format shown in Table 1-4. In no instance should 400 series stainless steels be supplied with a hardness in excess of HRC 30.

- 2. Identify in Table 1-4 if buckets are to be produced from bar-stock or an envelope forging. Produce any forging at temperatures between 1950–2025°F (1066–1107°C) and finish it at temperatures not lower than 1550–1600°F (843–871°C).
- 3. Supply the information supplied in Table 1-4 in advance of the manufacture of the buckets. This information will act as the target acceptance checklist by which the mechanical properties of the material used in the final product will be tested, compared, and reported.

Table 1-4
Source of Buckets/Blades and Their Mechanical Properties

Source of Bucket Material:		AISI:	
Bar Stock? ____Yes ____No		Envelope Forging ____Yes ____No	
Mechanical Properties	Bucket/Blade	Cover	Pins
Tensile Strength (ksi or MPa)			
0.2% Yield Strength (ksi or MPa)			
Elongation (%)			
Reduction of Area (%)			
Charpy V-Notch (ft-lb or N-m)			
Hardness (BHN)			

1.4.3 General Requirement: Material and Fatigue Properties

- 1. To support results reported from a structural analysis, report in Table 1-5 the Young’s Modulus, Poisson’s Ratio, and density that are used to calculate stresses and natural frequencies for each of the materials listed in Tables 1-3 and 1-4.
- 2. To support results where a fatigue analysis is required, report in Table 1-6 the mechanical properties that are used to calculate low-cycle and high-cycle initiation life for each of the materials listed in Tables 1-3 and 1-4.
- 3. To support results where an analysis of damage tolerance is required, report the stress intensity factor and threshold value for the respective components in Table 1-8 for each of the materials listed in Tables 1-3 and 1-4.
- 4. If buckets are to be operated in or beyond the Wilson line, list in Table 1-7 the K_{ISCC} and SCC growth rate data for each of the materials listed in Tables 1-3 and 1-4.
- 5. If the stage operating temperature is greater than 800°F (427°C), report in Table 1-8 the specific heat, thermal conductivity, and coefficient of thermal expansion for each of the materials listed in Tables 1-3 and 1-4.

Steam Turbine Blade/Bucket Procurement Guidelines

Table 1-5
Basic Material Properties Used in Structural Analysis

Material Properties	Bucket/Blade	Cover	Pins	Disk
Young's Modulus (ksi or MPa)				
Poisson's Ratio				
Density				

Table 1-6
Additional Material Properties Used for Fatigue Life Prediction

Fatigue Properties	Bucket/Blade	Cover	Pins	Disk
Fatigue Strength Coefficient [σ'_f]				
Fatigue Strength Exponent [b]				
Fatigue Ductility Coefficient [ϵ'_f]				
Fatigue Ductility Exponent [c]				
Fracture Toughness (K_{IC})				
Threshold Stress Intensity (ΔK_{th})				

Table 1-7
Material Properties for Further Analysis of SCC in Wet Regions

Material Properties*	Bucket/Blade	Cover	Pins	Disk
SCC Growth Rate* [da/dt]				
SCC Threshold Value* [K_{ISCC}]				
*Not required unless the stage operates within or beyond the Wilson Line				

Table 1-8
Material Properties Used in Structural Analysis of High-Temperature Buckets

Material Properties	Bucket/Blade	Cover	Pins	Disk
Specific Heat*				
Thermal Conductivity*				
Coefficient of Expansion*				
* Not required unless the stage operating temperature is greater than 850°F (454°C)				

1.5 Erosion/Corrosion Protection

1.5.1 General Requirement: Surface Treatments

- 1. Report in Table 1-9 any surface treatments, such as flame hardening, shot peening, or coating, to be applied to the buckets.
- 2. If Yes is indicated to any of the treatments, then conformity with Section 1.5.1.1 is required.

1.5.1.1 Subrequirement: Flame Hardening/Shot Peening

- 1. Report in Table 1-9 the details for any planned induction hardening, flame hardening, or shot peening to the buckets.
- 2. Report any type of coating to be used along with the expected duration or life of the coating.
- 3. Report a description of the procedure and requirements for any flame hardening or induction hardening to be performed on the buckets.

Table 1-9
Erosion/Corrosion Protection

Planned Treatments	Bucket/Blade	Regions To Be Treated*
Induction Hardening	Yes - No	
Flame Hardening	Yes - No	
Shot Peening	Yes - No	
Coating	Yes - No	Est. Coating Life ____ Hours
Description of Procedure:		
* Tenon, cover, airfoil leading edge, airfoil trailing edge, tie wire, root, disk attachment		

1.6 Structural Reliability – Low Cycle Fatigue

1.6.1 General Requirement: Structural Analysis Results

- 1. Report a summary of stress and frequency results for each type of bucket, conforming to the formats of Tables 1-10 through 1-12.
- 2. Material properties used as input for the structural analysis will be those in Table 1-4.

Steam Turbine Blade/Bucket Procurement Guidelines

3. If dimensions are obtained by reverse engineering, provide the finite element (FE) model used to obtain stress and frequency results, along with the buckets.
4. Obtain at-speed frequency information on the first four fundamental nodal diameter (ND) mode families by FE analysis (FEA) or testing.
5. For any low cycle fatigue (LCF) or high cycle fatigue (HCF) analysis results provided as part of this procedure, attach, as an addendum, the stress-strain curve and the S-N (strain versus number of cycle to failure) curve used as input.
6. Obtain stress results by means of ~~FE~~ **FE analysis** in accordance with the modeling criteria specified in Section 1.6.1.1.

1.6.1.1 Subrequirement: Finite Element Modeling

1. Report in Table 1-10 the FEA program and revision number used to perform any analysis of the components.
2. Derive the stress results required in this procedure from a three-dimensional, linear-elastic FE model of a blade-disc with a FE model comprised of no less than 5000 solid elements. The element aspect ratio should be in the range of 0.2 to 5.0.
3. Use a minimum grid of 2x6 elements in the airfoil section. In modeling the root attachment, use at least two layers of elements in the hook notch fillet regions.
4. For calculating blade-disk natural frequencies and dynamic stresses, a three-dimensional 360° fully bladed disc model is required. Use no less than 12 master degrees of freedom (DOF) to represent the airfoil, that is, 6 in the tangential direction and 6 in the axial direction.

1.6.2 General Requirement: Steady Operating Stress

1. Report in Table 1-10 results from a structural analysis to summarize the maximum steady *elastic* stress (ksi or MPa) (equivalent and principal) that occurs under centrifugal loads at full speed operation for each of the key structural features of the bucket.
2. Indicate any elastically calculated stress in Table 1-10 that is greater than the material yield strength as such. These stresses should be further subject to conversion into true stress and strain in accordance with the procedures of Section 1.6.2.1. Report results in Table 1-11.

Table 1-10
Summary of Calculated Steady Stresses

FE Program Used:		Revision #	
Structural Feature Material Yield Strength ____ksi (MPa)	Max Equivalent Elastic Stress ksi (MPa)	Max Principal Elastic Stress ksi (MPa)	Local Yielding?*** Yes or No
Cover: (Shroud/Integral)*			
Tenon*			
Tie Wire – Lashing Lug*			
Airfoil – Leading Edge			
Airfoil – Trailing Edge			
Blade Root			
Disk Attachment			
* If not applicable, indicate with NA.			
** Indicate Yes if the reported elastic stress exceeds the material yield strength.			

1.6.2.1 Subrequirement: True Stress

- 1. Derive true stress either by means of an elasto-plastic FE analysis of the region or by applying Neuber’s approach defined as follows.
- 2. Define the Neuber’s hyperbola by the elastic stress (σ_e) and Young’s modulus (E), using Equation 1-1.

$$\sigma_e^2 = \epsilon \cdot \sigma \cdot E$$

Eq. 1-1

Couple Neuber’s hyperbola with the stress-strain relationship using Equation 1-2, where E , K , and n are material stress-strain properties.

$$\epsilon = \frac{\sigma}{E} + \left(\frac{\sigma}{K}\right)^{1/n}$$

Eq. 1-2

- 3. Obtain the true strain by solving the two equations simultaneously. Report results in Table 6-2.
- 4. For any analysis of fatigue damage, base mean stress on the true stress, not the elastic stress value.

Table 1-11
Calculated True Stress in Identified Regions of Local Yielding

Structural Feature	Max Equivalent Elastic Stress ksi (MPa)	True Stress ksi (MPa)**	Local Yielding?*** Yes or No
Cover: (Shroud/Integral)*			
Tenon*			
Tie Wire – Lashing Lug*			
Airfoil – Leading Edge			
Airfoil – Trailing Edge			
Blade Root			
Disk Attachment			
* If not applicable, indicate with NA.			
** Covert maximum equivalent stress using formula from Subrequirement 6.4.1			
*** Indicate Yes if the true stress still exceeds the material yield strength.			

1.6.3 General Requirement: Low Cycle Fatigue - Crack Initiation

- Where the calculated stress exceeds the material yield strength, evaluate the crack initiation life associated with start-stop cycles (for example, LCF) of the turbine using the “local strain approach” and in accordance with Section 1.6.3.1.
- Report results in Table 1-12.

1.6.3.1 Subrequirement: Low Cycle Fatigue Life Prediction

- Base the calculated plastic strain amplitude (ϵ_p) and the strain versus number-of-cycles-to-failure (S-N) curve on an operating history comprised of 12,000 start-stop cycles experienced over 30 years.
- Account for a total of one overspeed cycle per year at 110% rated speed in the number of cycles estimated to initiate cracks.
- Identify the values used to represent both the plastic strain amplitude and S-N curve used for the LCF analysis. Use Equation 1-3 to calculate the number of start-stop cycles that the region identified as critically stressed can experience.

$$N_f = \frac{1}{2} \left(\frac{\epsilon_p}{\epsilon_f} \right)^{\frac{1}{c}}$$

Eq. 1-3

Where ϵ_f and c are LCF growth parameters to be identified in Table 1-12.

Table 1-12
LCF Crack Initiation Life for Identified Regions of Local Yielding

Structural Feature	True Stress ksi (MPa)	Plastic Strain (ϵ_p)	Est. Start-Stop Cycles
Cover: (Shroud/Integral)*			
Tenon*			
Tie Wire – Lashing Lug*			
Airfoil – Leading Edge			
Airfoil – Trailing Edge			
Blade Root			
Disk Attachment			
True fracture ductility ϵ_f applied:			
Fatigue ductility exponent (c) applied:			
* If not applicable, indicate with NA.			

1.6.4 Acceptance Criteria: Low Cycle Fatigue Life Limits

1. All structural features should have predicted stress levels that do not exceed the material yield strength or should achieve a predicted LCF life of not less than 300 start-stop cycles. If an LCF life of less than 300 start-stop cycles is reported in Table 1-12, a modification, supported with an FE analysis, may be required to demonstrate that the modified design produces a true stress that achieves an LCF endurance limit of 300 cycles or greater.
2. For units operated in a base load mode, the LCF limit may be relaxed to 500 cycles if the predicted dynamic stress from any given mode of vibration does not exceed 3 ksi (20.685 MPa). A dynamic stress analysis as defined in Section 1.7 is required to show compliance with this criterion.
3. For a unit cycled more than 100 start-stops per year, the LCF limit should remain no less than 15,000 cycles *and* the predicted dynamic stress from any given mode of vibration also may not exceed 3 ksi (20.685 MPa). A dynamic stress analysis as defined in Section 1.7 will be required to show compliance with this criterion.

1.7 Structural Reliability - High Cycle Fatigue Interaction

1.7.1 General Requirement: Identification of Natural Frequencies

1. Identify blade-disk frequency results obtained by either calculation or testing by their nodal diameter (ND) mode family for each of the first four fundamental blade modes, and report the results in Table 1-13. Also in Table 1-13, report the nozzle passing frequency for the stage.
2. Plot the ND modes shown in Table 1-13 on a frequency interference diagram (FID), with the number of ND modes forming the abscissa of the diagram equal to the total number of blade groups in the row divided by two. Plot the frequency interference diagram and supply it as an addendum to this table.
3. For free standing buckets or an arrangement where a continuous tie is formed between the buckets, the maximum ND is equal to the number of blades divided by two.

1.7.2 Acceptance Criteria: Detuning From Resonance

1. Adequately tune all blade-disk fundamental modes shown in Table 1-13 to avoid resonance with nearest per-revolution force (or engine order). Adequate detuning is defined as having each of the calculated at-speed natural frequencies provide a margin greater than 15 Hz from the nearest per-revolution force (engine order).
2. If tested frequencies are substituted for calculated frequencies, frequencies tested at speed must provide a margin greater than 10 Hz from the nearest per-revolution forcing. Frequencies obtained in a spin-pit must be in accordance with the conditions of Section 1.8.4.
3. Identify in Table 1-14 all nodal diameter modes with a margin of 15 Hz or less. Also identify in Table 1-14 all nodal diameter modes within 5% of the nozzle passing frequency (NPF).
4. A detuned response analysis is required for any mode with a margin greater than 10 Hz but less than 15 Hz. A resonant response calculation is required for any mode that is within 5% of the NPF of the stage.

Table 1-13
Blade Disk Natural Frequencies (At Operating Speed)

	Stage Nozzle Passing Frequency?_____ Hz			
	Frequencies Shown Are: _____ Calculated _____ Measured			
Nodal Diameter Number	Mode A (Hz)	Mode B (Hz)	Mode C (Hz)	Mode D (Hz)
Nodal Diameter # 0				
Nodal Diameter # 1				
Nodal Diameter # 2				
Nodal Diameter # 3				
Nodal Diameter # 4				
Nodal Diameter # 5				
Nodal Diameter # 6				
Nodal Diameter # 7				
Nodal Diameter # 8				
Nodal Diameter # 9				
Nodal Diameter # 10				

Table 1-14
Modes with Less Than 15 Hz Margin of Detuning from Resonance

ND Mode Family	ND# and Frequency	Nearest Engine Order	Margin
Mode ____	ND#____at_____ Hz	____ per-rev @_____ Hz	Hz
Mode ____	ND#____at_____ Hz	____ per-rev @_____ Hz	Hz
Mode ____	ND#____at_____ Hz	____ per-rev @_____ Hz	Hz
Mode ____	ND#____at_____ Hz	____ per-rev @_____ Hz	Hz
NPF	ND#____at_____ Hz	NPF @_____ Hz	Hz
	ND#____at_____ Hz	NPF @_____ Hz	Hz

Steam Turbine Blade/Bucket Procurement Guidelines

1.7.3 General Requirement: Resonant Response Analysis

1. Provide a resonant response stress calculation for each of the first four nodal diameter mode families identified in Table 1-13 to identify the locations of maximum dynamic stress when the blade-disk modes encounter a resonant vibration condition.
2. Perform the resonant response stress calculation in accordance with Section 1.7.3.1.
3. Report in Table 1-15 maximum resonant stress at each structural feature of the blade-disk for nodal diameter mode families A through D.
4. Supply detailed contour plots as an addendum for each of the first four nodal diameter mode families that show the magnitude and distribution of resonant stress (ksi or MPa) in a single bucket under an assumed condition of resonance.

1.7.3.1 Subrequirement: Resonant Dynamic Stress Calculation

1. Estimate the resonant response (x) of a bucket by solving the differential equation shown in Equation 1-4.

$$M\ddot{x} + C\dot{x} + Kx = \vec{S} \cdot F_o \cdot e^{i(\omega t + \phi)} \quad \text{Eq. 1-4}$$

Where: M , C , and K are the mass matrix, damping matrix, and stiffness matrix respectively.

S is the stimulus.

F_o is the steam bending force on the airfoil.

e is the exponential base.

i is an imaginary unit.

ωt is the forcing frequency in radians per second.

ϕ is the phase angle blade.

2. To calculate resonant response, assume a 10% stimulus (S) at NPF and at 1 per-revolution.
3. For low per-revolution forcing (2–10) of LP blades, assume a 3% stimulus. For low (2–10) per-revolution forcing of 1st row HP, IP, and LP blades, assume a 4% stimulus. Assume a 1% stimulus for forces beyond the 10th per-revolution.
4. Use a 0.15% critical damping ratio (ξ) for free standing blades and grouped blades. If the bladed disc has damping elements such as loose tie wire or “Z” cut shrouds, assume a 1.5% damping ratio.

Table 1-15
Resonant Dynamic Stress for the First Four Nodal Diameter Mode Families

Region	Mode A (Hz) ksi (MPa)	Mode B (Hz) ksi (MPa)	Mode C (Hz) ksi (MPa)	Mode D (Hz) ksi (MPa)
Cover: (Shroud/Integral)				
Tenon				
Tie Wire – Lashing Lug				
Airfoil – Leading Edge				
Airfoil – Trailing Edge				
Blade Root				
Disk Attachment				

1.7.4 General Requirement: Detuned Response Analysis

1. All modes with a margin from resonance greater than 10 Hz and less than 15 Hz should have operating dynamic stress estimated in a non-resonant (detuned) condition using Equation 1-5.
2. Report in Table 1-16 results for each mode along with the natural frequency of the mode, the nearest forcing frequency, and the forcing ratio.

1.7.4.1 Subrequirement: Detuned Dynamic Stress Calculation

1. In Equation 1-5, use a 0.15% critical damping ratio (ξ) for free standing blades and grouped blades.
2. If the bladed disc has damping elements such as loose tie wire or “Z” cut shrouds, assume a 1.5% damping ratio.

$$\sigma_d = \frac{2 \cdot \xi \cdot \sigma_R}{\sqrt{(1 - \mu^2)^2 + (2 \cdot \mu \cdot \xi)^2}}$$

Eq. 1-5

Where:

- ξ is the critical damping ratio (c/c_c).
- c is the damping coefficient.
- c_c is the critical damping.
- μ is the frequency ratio. $\mu = \omega / \omega_n$.
- ω is the forcing frequency in radians per second.
- ω_n is the natural frequency.
- σ_R is the calculated resonant stress.

Table 1-16
Estimated Detuned Dynamic Stress for Each Mode

ND Mode*	Mode A (Hz)	Mode B (Hz)	Mode C (Hz)	Mode D (Hz)
Forcing Frequency (Hz)				
Natural Frequency (Hz)				
Frequency Ratio				
Dynamic Stress**	Mode A (Hz) ksi (MPa)	Mode B (Hz) ksi (MPa)	Mode C (Hz) ksi (MPa)	Mode D (Hz) ksi (MPa)
Cover: (Shroud/Integral)*				
Tenon*				
Tie Wire – Lashing Lug*				
Airfoil – Leading Edge				
Airfoil – Trailing Edge				
Blade Root				
Disk Attachment				
*Identified in Table 1-14 as having a margin of 15 Hz or less				
**Calculated using formulas from General Requirement 1.7.4				

1.7.5 Acceptance Criteria: Dynamic Stress/High Cycle Fatigue

1. All structural features should operate within a predicted dynamic stress (resonant or detuned) of less than 3 ksi (20.685 MPa) for any ND modes within the first four mode families identified in Table 1-16.
2. Calculate allowable dynamic stress (σ_a) using Equation 1-6.

$$\sigma_a = (\sigma_f - \sigma_o) \left(2 \times 10^{10} \right)^b$$

Eq. 1-6

Where: σ_f and b are HCF growth parameters for the blade material reported in Table 1-17.
 σ_o is the mean stress.

3. If the predicted dynamic stress for any structural feature exceeds 8 ksi (55.16 MPa), a design modification, supported by analysis, is required.
4. If the estimated resonant dynamic stress for any mode predicted within 5% of nozzle passing frequency is greater than 8 ksi (55.16 MPa), a design modification is required, supported by analysis, to demonstrate compliance.

Steam Turbine Blade/Bucket Procurement Guidelines

5. If the dynamic stress is greater than 3 ksi (20.685 MPa) but less than 8 ksi (55.16 MPa), evaluate the rate of high cycle fatigue (HCF) damage for each mode of vibration and report it in Table 1-17. Perform the estimate of HCF damage in accordance with eq. 1-7, using the approach identified in Section 1.7.5.1.
6. The modified design should demonstrate that an HCF endurance limit exceeding 10^{10} cycles is achieved for the modes of concern.

1.7.5.1 Subrequirement: High Cycle Fatigue Damage

1. Base predicted HCF damage for each mode on the calculated dynamic stress amplitude (σ_d) and a stress versus number-of-cycles-to-failure (S-N) curve for the blade material.
2. Estimate crack initiation life (N_f) due to HCF based on the dynamic stress (σ_d) and the mean stress (σ_o) using Equation 1-7:

$$N_f = \frac{1}{2} \left(\frac{\sigma_d}{\sigma_f - \sigma_o} \right)^{1/b} \quad \text{Eq. 1-7}$$

Where:

σ_d is the dynamic stress.

σ_o is the mean stress.

σ_f and b are HCF growth parameters for the blade material reported in Table 1-17.

3. If a mode identified in Table 1-13 is within 10 Hz of the nearest per-revolution force, use the resonant dynamic stress in eq. 1-7.
4. If the margin is greater than 10 Hz, use the detuned dynamic stress amplitude in eq. 1-6.
5. Attach the S-N curve used to represent the blade material as an addendum.
6. Account for the effect of mean stress (σ_o) on HCF life in the prediction of HCF damage, where mean stress is based on the true stress and should also account for residual stress (σ_r).
7. Report results in Table 1-17 as estimated cycles to crack initiation.

Table 1-17
Estimated HCF Initiation Life for Modes < 10 Hz Margin From Resonance

Dynamic Stress For Each Mode	Mode @ ____ (Hz)*	Mode @ ____ (Hz)*	Mode @ ____ (Hz)*
	Cycles to Crack Initiation by High Cycle Fatigue**		
Cover: (Shroud/Integral)*	cycles	cycles	cycles
Tenon*	cycles	cycles	cycles
Tie Wire – Lashing Lug*	cycles	cycles	cycles
Airfoil – Leading Edge	cycles	cycles	cycles
Airfoil – Trailing Edge	cycles	cycles	cycles
Blade Root	cycles	cycles	cycles
Disk Attachment	cycles	cycles	cycles
True Fracture Strength (σ_f) Applied:			
Fatigue Strength Exponent (b) Applied:			
* Identified in Table 1-13 as having a margin of 15 Hz or less			
**Calculated using Equation 1-7			

1.7.6 Acceptance Criteria: Low Cycle Fatigue - High Cycle Fatigue Interaction

1. Consider as acceptable all blades with a predicted LCF life of greater than 15,000 start-stop cycles and predicted operating stress of less than 3 ksi (20.685 MPa).
2. For blades operated in base load units, any structural feature that fails to achieve a predicted LCF of greater than 300 but less than 500 start-stop cycles is further required to demonstrate that the calculated dynamic stress for any given mode remains lower than 3 ksi (20.685 MPa). If the dynamic stress exceeds 3 ksi (20.685 MPa), a modification is required.
3. For blades to be installed on units that experience 100 or more start-stop cycles per year, any structural feature that fails to achieve a predicted LCF life of 15,000 cycles must demonstrate that the predicted operating dynamic stress remains lower than 3 ksi (20.685 MPa) for any given mode. If the dynamic stress exceeds 3 ksi (20.685 MPa), a modification is required.
4. If the number of allowable start-stop (N_f) cycles and respective dynamic stress fails to achieve the aforementioned limits, a design modification is required, supported with an FE analysis to demonstrate compliance.

1.7.7 Acceptance Criteria: Stress Corrosion Cracking - High Cycle Fatigue Interaction

1. For any components operated beyond the Wilson line (that is, “wet” stages) where the steady stress is greater than 50% yield strength, a calculation is required to demonstrate that the operating dynamic stress does not exceed 3 ksi (20.685 MPa).
2. If the operating dynamic stress is higher than 3 ksi (20.685 MPa), a design modification is required, supported by analysis to demonstrate compliance.

1.7.8 Acceptance Criteria: Creep - High Cycle Fatigue Interaction

1. For any stages operated at 850°F (454.4°C) or higher where the creep strain is greater than 0.5%, a calculation is required to demonstrate that the operating dynamic stress does not exceed 3 ksi (20.685 MPa).
2. If the operating dynamic stress is higher than 3 ksi (20.685 MPa), a design modification is required, supported by analysis to demonstrate compliance.

1.7.9 General Requirement: High Cycle Fatigue in Heat-Affected Zone

1. Identify any structural feature of the bucket that requires welding and/or results in a heat-affected zone (HAZ). If the HAZ is left untreated, a calculation is required to demonstrate that the operating dynamic stress in the zone does not exceed 3 ksi (20.685 MPa).
2. If the operating dynamic stress is higher than 3 ksi (20.685 MPa), a design modification is required, supported by analysis to demonstrate compliance.

1.8 Quality Control Measures**1.8.1 General Requirement: Pre-Installation Frequency Testing**

1. As an initial check of the dynamic properties of the buckets, perform frequency tests first for individual components prior to acceptance and installation on the turbine.
2. Before delivery of the buckets, provide the *target frequencies* expected for each of the first three modes of a single blade when mounted in a fixture and frequency tested. Provide the target frequencies and test results in the format shown in Table 1-18.
3. The acceptance criteria for individual blades tested in a fixture is required to come within 2% of the target frequencies identified for the first two modes. For the third mode, a difference of less than 5% is allowed.

Steam Turbine Blade/Bucket Procurement Guidelines

- 4. The test rig should use a fixture that conforms to the original root, where the blade/bucket root can be pressed against the attachment to simulate a condition of normal centrifugal lock-up of the attachment.
- 5. Excite the blade using an instrumented hammer within a range sufficient to identify and document the frequencies of the first four modes for each blade.
- 6. Indicate the delivery of the frequency check results on any milestone schedule supplied in response to this procedure.

Table 1-18
Record of Frequency Tests for Individual Blades

	Mode 1	Mode 2	Mode 3	Mode 4
Target (± 2%)	Hz	Hz	Hz	Hz
Measured Blade #1	Hz	Hz	Hz	Hz
Measured Blade #2	Hz	Hz	Hz	Hz
Measured Blade #3	Hz	Hz	Hz	Hz
Measured Blade #N	Hz	Hz	Hz	Hz

1.8.2 General Requirement: Assembly Tolerances

- 1. For blades that rely on tangential entry root designs, the purchaser should check the tolerances of any accessible root load-bearing surfaces and compare them against the values specified in Section 1.3.1 before installation of the components in the turbine.
- 2. The allowable tolerance for a root attachment is specified at 0.005" (0.127 mm) for any given load-bearing surface.
- 3. To check the quality of root tolerances, take coordinate measurements at no fewer than five points per load-bearing surface.
- 4. Identify alternative root tolerance limits in advance.
- 5. For integral cover bucket designs in which a continuous linking is to be achieved by untwisting of the bucket under centrifugal force, identify the minimum and maximum allowable gaps at zero rpm before installation.
- 6. By means of analysis, demonstrate that at the minimum allowable gap size, centrifugal stresses in the covers between adjacent blades do not exceed 50% of material yield strength at full speed operation.
- 7. By analysis, demonstrate that for the maximum allowable gap size at zero rpm, centrifugal force will close the gaps at 80% of rotating speed.

1.8.3 General Requirement: Blade - Disk Frequency Testing at 0 rpm

- 1. Before delivery of the buckets, provide the target frequencies expected for each of the first three modes when mounted on a disk as an assembled row. As a final check of the assembled row, perform a modal frequency test after the installation of buckets is completed.
- 2. The measured frequencies should be within 2% of the target frequencies for the first two modes. For the third mode, a difference of less than 5% is allowed. If the root is loose, apply Loctite before the test. Submit results of the tests in the format shown in Table 1-19.
- 3. If the frequencies of the blade or blade group measured on the disk are 90% or less of the predicted zero-rpm frequencies, replace the blade or group.

Table 1-19
Record of Frequency Tests for Installed Blades/Blade Groups

	Mode 1	Mode 2	Mode 3	Mode 4
Target (± 2%)	Hz	Hz	Hz	Hz
Measured Blade #1	Hz	Hz	Hz	Hz
Measured Blade #2	Hz	Hz	Hz	Hz
Measured Blade #3	Hz	Hz	Hz	Hz
Measured Blade #N	Hz	Hz	Hz	Hz

1.8.4 General Requirement: Blade - Disk Frequency Testing

- 1. Perform telemetry testing to obtain frequency data for the two fundamental mode frequencies. Results should clearly show the frequencies near the rotor operating speed.
- 2. A minimum of six telemetry channels are required to test any row of blades in a vacuum chamber. Place two gauges above the platform on the trailing edge of the blade suction side. Place two gauges above any tie wire or connecting device. Place two thermocouples on the airfoil, one near the tip and one near the platform.
- 3. Record the frequency and thermocouple data during ramp-up and ramp-down by using a DC exciter. Provide a waterfall diagram for both ramp-up and down to display the frequency changes with rotor speed.
- 4. Determine the natural frequencies of the blade-disk under actual operating conditions by compensating for both the rotor speed and temperature of the simulated (spin-pit) test.

1.9 Nomenclature

The following table identifies nomenclature used within this procedure.

Table 1-20
Terminology Alternatives for Turbine Components [2]

Rotating Blades and Parts	Alternative Terms
Rotating blades	Buckets
Blade root	Serrations, attachments, fir trees, hooks, attachment base
Blade shank	Blade tail
Blade base	Platform
Blade airfoil	Vane, partition, foil
Pin and finger root	Pinned finger, fork-shaped fastening
Fir-tree (attachment)	Dovetail
Pins	Prongs
Tie wires	Lacing wires, lashing wires, arch bands, snubber, connectors
Shrouds	Covers, bands, cover bands, integral shrouds, spill strips
Tuned blade packets	Harmonic shrouding
Tenons	Rivets, pegs
Tenon rivet	Tenon upset, tenon head
Countersunk tenon rivet	Foxholed tenon
Dovetail	Steeple, roots and grooves
Blade group	Blade packet
Closing blade	Notch piece / blade
Stationary Blades and Parts	Alternative Terms
Stationary blades	Nozzles
Nozzle chests	Nozzle boxes, nozzle plate, nozzle chamber/block
Diaphragms	Partitions, blade ring/carrier, stationaries, rings
Stationary vanes	Nozzle foils, nozzle vanes, nozzle partitions
Other Components	Alternative Terms
Inlet	Bowl
Control stage	First stage, governing stage, partial admission stage, inlet stage.
Rotor	Shaft, wheel, spindles
Disc	Wheel
Keyways of discs	Anti-rotation pin slots
Disc-rim blade attachment	Steeple
Blade entry slot	Gate, notch
Seal	Sealing labyrinth, labyrinth seal, sealing fin, packing ring, packing, gland, sealing strip, spill strip
Turning gear	Barring gear
Pedestal	Standard
Turbine Section	Cylinder
Exhaust hood	Exhaust port
Turbine casing	Shell, cylinder
Sleeve rings	Snout rings, piston rings, inlet rings
Attemperators	Sprays

1.10 Materials and Properties

Tables 1-21 through 1-26 present details of material and mechanical properties on buckets and rotors. These details are drawn from the EPRI report *Turbine Steam Path Damage: Theory and Practice (Volumes 1 and 2)* [2, 3]. They are provided as further reference for comparing and contrasting the information requested in Tables 1-2 through 1-8 of this procurement procedure.

Table 1-21
Composition of Materials Commonly Used for LP Blades [2]

Element	12% Cr Stainless Steels				Titanium
AISI Type or European Designation	AISI 403 (Generic)	AISI 410 (Generic)	X20CrMoV121 (Example)	X20Cr13 (Example)	
Carbon	0.15±0.005	0.15±0.005	0.22	0.19	0.020–0.040
Manganese	1.00±0.030	1.00±0.030	0.40	0.53	
Phosphorus	0.04±0.005	0.04±0.005	0.017	0.017	
Sulfur	0.03±0.005	0.03±0.005	0.004	0.013	
Silicon	0.50±0.050	1.00±0.050	0.38	.024	
Chromium	11.5–13.0 ±0.150	11.5–13.0 ±0.150	12.4	13.3	
Molybdenum			0.49	0.03	
Nickel	0.60±0.030		0.96	0.43	
Tungsten					
Vanadium			0.28		4.1–4.5
Nitrogen				0.04	0.010–0.019
Copper				0.06	
Aluminum					6.2–6.6
Oxygen					0.12–0.20
Hydrogen					0.002–0.006
Iron					0.100–0.008
Titanium					Balance

Steam Turbine Blade/Bucket Procurement Guidelines

Table 1-21 (continued)
Composition of Materials Commonly Used for LP Blades [2]

Element	Precipitation-Hardened Materials			Duplex Steels	
	17-4 PH	15-5 PH	13-8 PH	Ferralium 255	
AISI Type or European Designation	AISI 630	X5CrNiMoCu145 (Example)	X3CrNiMoAl1382 (Example)	AISI	X3CrMnNiMoN 2264 (A905) (Example)
Carbon	0.07 max	0.04	0.03	0.04 max	0.02
Manganese	1.00 max	0.42	0.03	0.80	5.6
Phosphorus	0.03 max	0.024	0.004		0.007
Sulfur	0.03 max	0.010	0.003		0.002
Silicon	1.00 max	0.42	0.04	0.45	0.38
Chromium	15–17.5	14.5	12.7	26	25.8
Molybdenum	0.50 max	1.75	2.22	3.0	2.1
Nickel	3–5	4.83	8.47	5.5	3.8
Niobium		0.32			
Tungsten					
Vanadium					
Columbium					
Columbium + Tantalum	0.15–0.45 (or as 5X C; 0.45 max)				
Copper	3–5	1.52	0.01	1.7	
Aluminum			1.04		
Oxygen					
Hydrogen					
Nitrogen				0.17	0.33
Iron					
Titanium					

Table 1-22
Mechanical Properties of Materials Used for LP Turbine Blades [2]

Property	AISI Type 403/410 (Generic)	Precipitation Hardened 17-4 PH	Titanium (Ti-6Al-4V)	Duplex Stainless Steel (Ferralium 255)
Condition	Hardened and tempered at 648°C(1200°F)	Hardening temperature = 496°C (925°F)	Annealed	Plate, heat treated at 1120°C (2050°F), rapidly cooled
Specific Weight kg/m ³ (lb/in ³)	7750 (0.28)	7750 (0.28)	4430 (0.16)	7806 (0.282)
Modulus of Elasticity, GPa (10 ⁶ psi)	200 (29)	195 (28.5)	114 (16.5)	210 (30.5)
Tensile Strength MPa (ksi)	760 (110)		950 (138)	867 (125.8)
0.2% Yield Strength MPa (ksi)	585 (85)	1070 (155)	88 (128)	674 (97.8)
Elongation (%)	23	10	13	27
Reduction in Area (%)	60	41		
Brinell Hardness	225	375-438		
Endurance Limit MPa (ksi)	275 (40)	550 (80)	520 (75)	
Note: The mechanical properties for these materials are very dependent on manufacturing process, tempering temperature, and composition. The values are "typical" for the alloy and heat treatment shown. Use application-specific, as-measured properties for any analysis of blading.				

Steam Turbine Blade/Bucket Procurement Guidelines

Table 1-23
Composition and Properties of Materials Used for HP Turbine Blades [2]

Element	Martensitic Stainless Steel AISI Type 422 (Generic)	Austenitic Stainless Steel (Bohler Turbotherm 17 13 W)
Carbon	0.22±0.020	0.10
Manganese	0.69±0.030	
Phosphorus	0.02±0.005	0.03
Sulfur	0.03±0.005	0.003
Silicon	0.50±0.050	1.00
Chromium	11.5–12.5 ± 0.150	16.0
Molybdenum	0.93±0.050	
Nickel	0.76±0.030	13.5
Tungsten	0.97±0.050	2.80
Vanadium	0.21±0.050	
Thallium		0.50
Property	Martensitic Stainless Steel AISI Type 422 (Generic)	Austenitic Stainless Steel (Bohler Turbotherm 17 13 W)
Tensile Strength MPa (ksi)	967 (140)	538–732 (78–106) Quenched 635–830 (92–120) Hot & cold formed
0.2% Yield Strength MPa (ksi)	795 (115)	248 (36) Quenched 442 (64) Hot & cold formed
Elongation (%)	13	30% Quenched 25% Hot & cold formed
Reduction of Area (%)	25	
Brinell Hardness	293–341	
Charpy V-Notch Impact at Room Temperature m-kJ (ft-lb)	2.14–2.34 (15.5–17)	

Steam Turbine Blade/Bucket Procurement Guidelines

Table 1-24
Materials Commonly Used in the Construction of Rotors [2]

Component	Generic Name	ASTM Alloy Designation
LP Rotor	2.0 NiMoV	A293, Classes 2 & 3
	2.5 NiMoV	A293, Classes 4 & 5
	2.5 NiMoV	A470, Classes 2 & 3
	3.5 NiCrMoV	A470, classes 5 to 7
	20 Mn 5	None, (DIN, Wks, 1.1133)
	24 Ni 4	None, (DIN, Wks, 1.5613)
	24 Ni 12	None
	22 NiCrMoV 12	None
LP Disc	2.8 NiMoV	A294, Grades B & C
	3.5 NiCrMoV	A471, Classes 1 to 3
HP Rotor	1 CrMoV	A293, Class 6
	1 CrMoV	A470, Class 8
	12 CrMoV	A565, Gr. 616
	12 CrMoV	A768, Class 1
	-20 CrMoV 12 1	None (DIN, 1.4922)
	-22 CrMoWV 12 1	None (DIN, 1.8212)
	30 NiCrMoV 5 11	None (DIN, Wks. 1.6946)
HP Disk	1 CrMoV	A471, Class 5 & 10
	26 NiCrMoV 11 5	None (DIN, Wks. 1.6948)

Steam Turbine Blade/Bucket Procurement Guidelines

Table 1-25
Composition and Properties of Commonly Used Rotor and Disk Materials [2]

Property/Composition	LP Rotor 3.5 NiCrMoV (A470 Class 6) ¹	LP Disc 3.5 NiCrMoV (A471, Class 3) ²	HP Rotor 12CrMoV (A565, Gr.616) ³ (Heat-treated)
Composition			
Carbon	0.28 max	0.28 max	0.20–0.25
Manganese	0.20–0.60 (0.40 max) ⁴	0.70 max	0.5–1.0
Phosphorus	0.012 max	0.012 max	0.05 max
Sulfur	0.15–0.30 ⁵ (0.10 max) ⁴	0.15–0.35 ⁵	0.50 max
Nickel	3.25–4.00	2.0–4.0	0.5–1.0
Chromium	1.25–2.00	0.75–2.0	11.0–12.5
Molybdenum	0.25–0.60 ⁶ (0.25–0.45) ⁴	0.20–0.70	0.90–1.25
Vanadium	0.05–0.15	0.05 min	0.20–0.30
Antimony	Note 4 and 7	Note 7	
Tin	Note 4		
Tungsten			0.90–1.25
Mechanical Properties			
Tensile Strength, Min, MPa (ksi)	725-860 (105-125)	760 (110)	965 (140)
Yield Strength, Min, MPa (ksi), 0.2% offset	620 (90)	690-825 ⁸ (100-120) ⁸	760 (110)
Elongation in 50 mm or 2 in., Min., %		18	13
*Longitudinal Prolongation	18		
*Radial Body	17		
Reduction in Area, Min., %		47	30
*Longitudinal Prolongation	52		
*Radial Body	50		
FATT 50 max	-7°C (20°F)	-18°C (0°F)	
Room Temp. Impact, Min. J (ft. lb.)	61.2 (45)	61.2 (45)	11 (8)
Brinell Hardness			302-352
Notes: 1. ASTM A470, Standard Specification for Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts. 2. ASTM A471, Standard Specification for Vacuum-Treated Alloy Steel Forgings for Turbine Rotors, discs and wheels. 3. ASTM A565, Standard Specification for Martensitic Stainless Steel Bars, Forgings, and Forging Stock for High-Temperature Service. 4. Special Composition requirements to minimize temper embrittlement. 5. May be vacuum-carbon deoxidized, silicon, 0.10 max. 6. If required due to operating temperatures, 0.40 % Mo may be specified. 7. To be reported for information only. 8. 0.2% offset.			

Steam Turbine Blade/Bucket Procurement Guidelines

Table 1-26
Composition of Selected European Rotor Materials [2]

Rotor Material	Din Wks. No.	C	Si	Mn	P	S	Cr	Mo	Ni	V	W
20 Mn 5	1.1133	0.17–0.23	0.30–0.60	1.00–1.30	0.035	-	-	-	-	-	-
24 Ni 12	-	0.25 nom	-	0.90 nom	-	-	-	-	3.0 nom	-	-
22 NiCrMoV 12	-	0.25 nom	-	0.47 nom	-	-	1.50–2.00	0.40–0.60	2.80–3.20	0.11	-
26 NiCrMo 11 5	1.2726	0.22–0.30	0.30–0.50	0.20–0.40	0.03	0.03	0.60–0.90	0.20–0.40	1.30–1.60	0.15	0.20
X20 CrMoV 12 1	1.4922	0.17–0.23	0.50	1.00	0.030	0.030	10.0–12.5	0.80–1.20	0.30–0.80	0.25–0.35	-
X21 CrMoWV 12 1	1.4926	0.20–0.26	0.50	0.30–0.80	0.25	0.20	11.0–12.5	0.80–1.20	0.30–0.80	0.25–0.35	0.30
24 Ni 4	1.5613	0.20–0.28	0.15–0.35	0.60–0.80	0.035	0.035	0.30	-	1.00–1.30	-	-
24 Ni 8	1.5633	0.20–0.28	0.15–0.35	0.60–0.80	0.035	0.035	0.30	-	1.90–2.20	-	-
30 NiCrMoV 5 11	1.6946	0.28–0.32	0.30	0.15–0.40	0.015	0.018	1.20–1.80	0.25–0.45	2.4–3.1	0.05–0.15	-
26 NiCrMoV 14 5	1.6957	0.22–0.32	0.30	0.15–0.40	0.015	0.018	1.20–1.80	0.25–0.445	3.4–4.0	0.05–0.15	-
21 CrMoV 5 11	1.8070	0.17–0.25	0.30–0.60	0.30–0.60	0.035	0.035	1.20–1.50	1.00–1.20	0.60	0.25–0.35	-

1.11 Stress and Fatigue Life

Figure 1-4 provides additional detail on the relationship of relevant terms used in Sections 1.7.5 and 1.7.6 to estimate crack initiation life. Table 1-27 presents details of cyclic properties drawn from the EPRI report *Turbine Steam Path Damage: Theory and Practice (Volumes 1 and 2)* [2, 3]. They are provided as further reference for comparing and contrasting the information requested in Tables 1-5 and 1-6 of this procurement procedure.

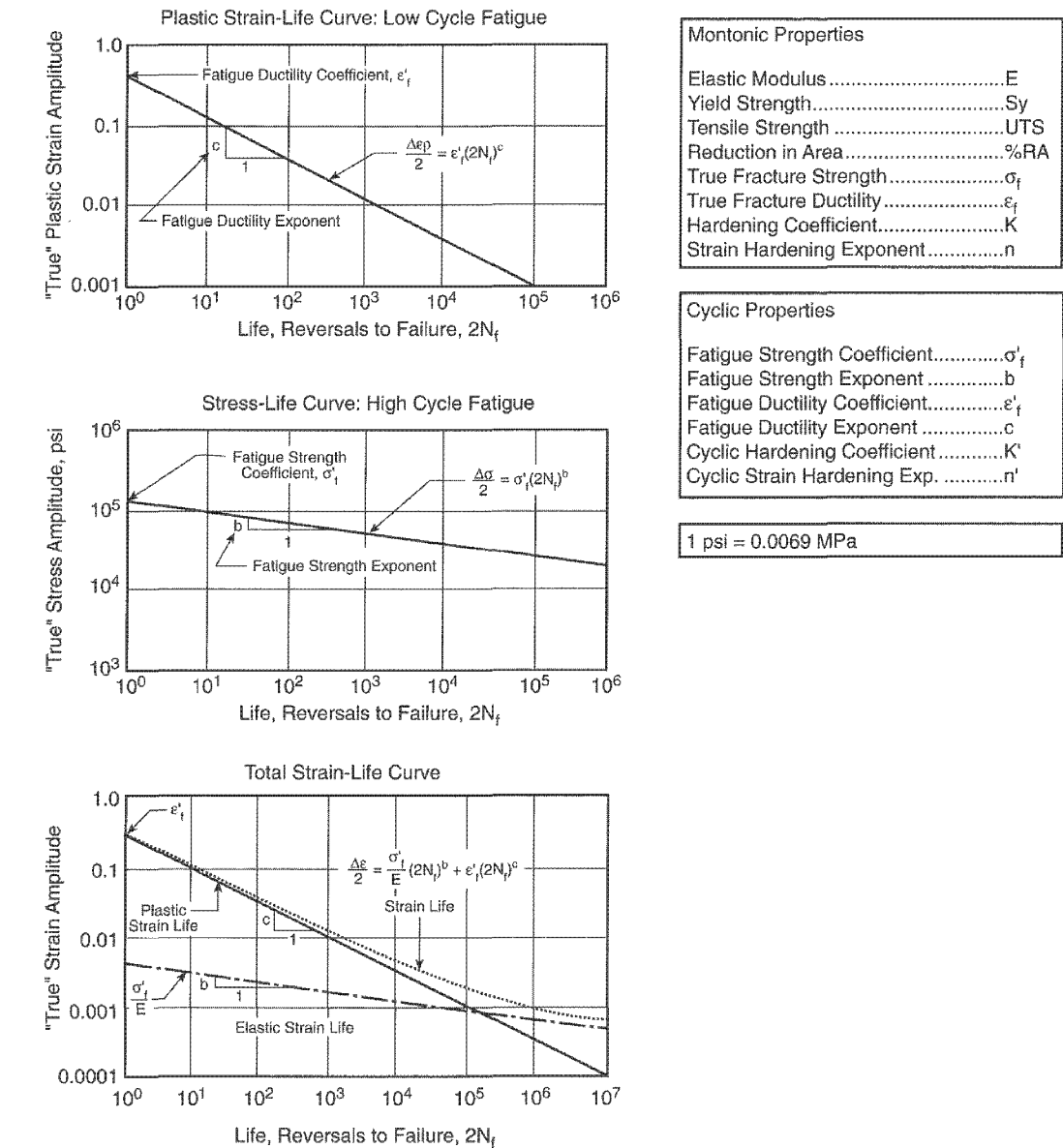


Figure 1-4
Definition and Formulation of Stress and Fatigue Life Curves [4]

Table 1-27
Cyclic Fatigue Properties for 12% Cr Stainless Steel [3]

Material	Fatigue Strength Coefficient, σ'_f (MPa)	Cyclic Strain Hardening Coefficient, n'	Notes
Type 403	962	0.110	High strain rates
Type 403	932	0.128	Lower strain rates
Type 403	1172	0.125	
Type 410	1472	0.143	For $\Delta\epsilon_p < 1\%$
Type 410	1472	0.218	For $\Delta\epsilon_p > 1\%$
Type 422	1216	0.093	Higher strain rates
Type 422	1249	0.099	Lower strain rates

A

EXAMPLE OF A TURBINE BUCKET RFQ

This appendix presents an example of a bid package that is designed to solicit a replacement row of blades. In this example, a low-pressure L-1 row is specified. Detailed information required to customize the bid package is identified in brackets, for example, [plant name].

The package is organized into five parts:

- Part 1 establishes the scope of the bid, under whose direction the bid is being conducted, and basic issues or conditions that govern the evaluation, selection, and schedule of the award to a supplier.
- Part 2 provides a format that each response is requested to follow. Providing a format generally makes it easier to compare and contrast the information that is identified as most relevant to the buyer.
- Part 3 gives details on the type and operating conditions for the unit as required to provide potential suppliers with sufficient information to determine if they can offer replacement parts. Part 3 also allows the plant to identify any special issues or concerns associated with delivery, design, or service that are particularly relevant in the final consideration of any bid.
- Part 4 itemizes the technical criteria that are used to control each step of the supplier's process, from selection of materials to installation of the row. As noted throughout the example, this section is designed to use selected technical criteria identified in Sections 1 and 2 of Volume 3 [11] of the *Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections* series. If balancing is required as in the example, Sections 1 and 2 of Volume 3 are referenced.
- Part 5 lists a number of ASTM specifications that are relevant to the treatment, composition, design, and manufacture of turbine buckets. These are referenced as basic industry standards that any qualified supplier would be expected to follow.

The last section contains three attachments. Part 1 is the format to summarize the essential cost elements and conditions of purchase for the bid (referenced under Part 2). The bidder's proposed schedule for delivery is established in Part 2 with required documentation to be supplied at identified milestones. Part 3 provides a summary of the technical criteria used to assess and/or accept the quality of work performed under the contract. This attachment provides a form by which final acceptance can be determined by the plant.

Example of a Turbine Bucket RFQ

[EXAMPLE]

REQUEST FOR QUOTATION

REPLACEMENT OF (Row Number) BUCKETS

FOR PLANT [NAME] UNIT [NUMBER]

Prepared by:

Name

Address

Acting on behalf of:

Operator

Address

Response Requested by: [DATE]

Table of Contents

1. SCOPE AND AUTHORITY
 - 1.1 Request for quotation
 - 1.2 Minimum Acceptance Criteria
 - 1.3 Other Criteria
 - 1.4 Warranty and Liquidated Damages
 - 1.5 Evaluation and Selection Procedure
 - 1.6 Schedule for Award
 - 1.7 Proprietary Information
 - 1.8 Contacts
 2. RESPONSE FORMAT
 3. BACKGROUND/GENERAL DESCRIPTION OF UNIT
 - 3.1 Description of Unit
 - 3.2 Issues with Present Row
 4. TECHNICAL CRITERIA
 - 4.1 General Information, Codes and Standards
 - 4.2 Component Materials
 - 4.3 Part Numbering
 - 4.4 Erosion Shields
 - 4.5 Shot Peening/Surface Finishes
 - 4.6 Manufacturing Criteria
 - 4.7 Root Attachment/Cover Tolerances
 - 4.8 Frequency Testing
 - 4.9 Moment Weighing
 - 4.10 Shipping of Parts
 - 4.11 Pre-Planning Support and Coordination
 - 4.12 Removal of Original Row
 - 4.13 Preparation of Disk and Installation of Row
 - 4.14 Inspection of New Row
 - 4.15 Balancing
 5. REFERENCES
- ATTACHMENTS
- Part 1: Costs and Conditions of Purchase
- Part 2: Schedule and Documentation
- Part 3: Summary of Acceptance Criteria

Example of a Turbine Bucket RFQ

1. SCOPE AND AUTHORITY

1.1 REQUEST FOR QUOTATION

Defined within this specification are the requirements to supply and install a single row of LP [identify row number] buckets for use in the low-pressure turbine of the [Plant name] Unit [number] owned and operated by [Name of Owner]. The buckets rely on a [identify] type root-disk attachment design. In accordance to this request, a total of [state number] buckets are to be supplied, [including a notch blade and its counterpart for balancing purposes if an axial entry type root attachment design is involved]. [State number] of buckets are to be installed in the row, and five identical buckets are to be supplied as spares. The manufacturer [supplier] of the new row shall be further responsible for (1) disassembly and reassembly of the rotor as required for removal of the old L-1 row, (2) installing the new L-1 row, (3) performing a slow-speed balance of the rotor after installation of the new row, and (4) performing a high-speed balance of the rotor during startup and operation. Removing old buckets and installing new design buckets should be identified as a separate cost from the manufacture of new buckets.

1.2 MINIMUM ACCEPTANCE CRITERIA

1. The new row must be compatible with the existing stationary nozzles and other components within the LP turbine.
2. A grouping or linkage strategy is to be used that ensures the first four fundamental modes of vibration will operate at least 10 hertz from the nearest resonant frequency.

1.3 OTHER CRITERIA

1. The new row of buckets should seek to improve the efficiency of the low-pressure turbine. The supplier shall specify the extent of efficiency improvements, if any.
2. Shot peening/coating should be considered around tie-wire holes, on covers and tenons, on bucket dovetail surfaces, and on the airfoil vane around erosion shields or in areas requiring brazing and welding. The supplier shall specify the areas where shot peening shall be performed, if any.

1.4 WARRANTY AND LIQUIDATED DAMAGES

1. The new row shall be warranted from fatigue or failure for a period of [state] years or [state] operating hours and [state] start-stop cycles, whichever comes first.
2. The supplier shall provide for liquidated damages for bucket shipment from the manufacturing facility, on-site delivery to the plant site, and total installation time at the plant site. A bonus for early delivery and installation will be considered.
3. Any bucket that fails to conform to the technical requirements as specified within this package will be replaced at no cost to the purchaser.

1.5 EVALUATION AND SELECTION PROCEDURE

- Interested parties are invited to prepare and submit a response in three parts to this request for quotation (RFQ). Responses should be in accordance with the information as detailed in Section 2.0 of this RFQ and conform to the formats reflected in the section "ATTACHMENTS."
- All responses are to be directed to [Name Contact], who are acting as agents on behalf of [Unit Operator] to establish compliance of the offer with the technical requirements specified within this bid package.
- Bids that offer replacement designs that are considered to be technically feasible will be forwarded to the plant for final selection based on price and delivery.
- Issue of a purchase order will be contingent upon final negotiation of the supplier's claims and guarantees.

1.6 SCHEDULE FOR AWARD

- A replacement row of buckets is being sought for delivery before [state date], to be installed no later than [state date].
- To comply with this schedule, all responses must be received by [Contact] no later than [state time, day, and date] to be considered further.
- A letter of intent to purchase is expected to be issued three weeks after receipt of the quotation.
- A proposed time schedule is supplied in Part 2, with milestones identified. Suppliers are requested to complete this schedule.
- Updates to the final schedule for delivery will be supplied on a weekly basis during manufacture and on a daily basis during installation.

1.7 PROPRIETARY INFORMATION

All information provided in response to this RFQ will remain confidential. No proprietary information is requested to demonstrate compliance with the technical acceptance criteria at this time beyond completion of the checklist in the attachments, Part 2.

1.8 CONTACTS

All quotations are to be mailed to:

[Mailing Address]

Attention: [Key Contact]

Questions regarding the technical contents of this RFQ should be directed to [Key Contact] at [Phone and Fax] or [email address].

Example of a Turbine Bucket RFQ

2. RESPONSE FORMAT

Responses to this Request for Quotation are to be organized as three parts, relying on the forms that are attached at the end of this document. A response should consist of the following:

- Cover Letter –Contact name and address and request for formal consideration of bid.
- Part 1 – Cost to complete scope as defined in the bid package
- Part 2 – Schedule for deliverables
- Part 3 – Checklist of technical requirements and acceptance criteria

Any issues with stated requirements should be noted and attached to each respective section.

Part 1 presents a breakdown of the total cost to (1) manufacture, (2) ship, (3) prepare, (4) install and (5) slow-speed balance a row of buckets on the [Plant/Unit Number] turbine-generator, located in [site]. Information in Part 1 should include:

- A firm price for the manufacture of [total number] buckets and all attachment hardware to include notch buckets, oversized buckets, etc. If a titanium notch bucket is to be employed, a normal titanium bucket should also be supplied as a counterbalance. The cost for a total of five spare buckets is also to be provided as a separate line item.
- A statement as to any necessary labor, tools, and equipment that the supplier requires for removing, cleaning, testing, and assembling the buckets and its assembly components. Disassembly and reassembly of the turbine as necessary for bucket removal and replacement will be performed by the supplier. Any other resources necessary for bucket removal and assembly will be provided by the supplier.
- A statement as to any necessary technical support, labor, and equipment required by the supplier to perform the slow-speed and high-speed balance of the low-pressure rotor.
- A rate schedule for any backup factory support (if any) to resolve assembly problems or issues.
- Pricing for any work shall include meals, travel, and other expenses necessary for the work to be performed.

Part 2 is a schedule of milestones and documentation to be supplied at the completion of each milestone. Suppliers are requested to indicate a reasonable timetable. Information in Part 2 should include:

- A detailed schedule or standard checklist to monitor each separate activity to be undertaken on-site, such as, (1) disassembly of the machine/unit, (2) removal of the old row, (3) preparation of the wheel for the bucket assembly, (4) assembly of the buckets, (5) necessary machining and NDE or other tests that may be required, (6) slow-speed balancing the rotor after bucket installation, (7) assembly of the machine, and (8) high-speed balancing the rotor during startup and operation.

- Supplier checklists associated with removal of the old buckets, installation of the new buckets, and slow-speed/high-speed balancing of the rotor shall be provided to the plant contact person prior to leaving the site.

Part 3 is a summary checklist of itemized technical requirements and criteria associated with the purchase of the new buckets. Suppliers are requested to indicate their compliance with these requirements or to offer alternative standards or criteria.

Example of a Turbine Bucket RFQ

3. BACKGROUND/GENERAL DESCRIPTION OF UNIT

3.1 GENERAL DESCRIPTION OF UNIT

The [XXXXXXX Unit X] turbine-generator operates with a live steam of [1250 psi/953°F], is rated at [500 MW], and was manufactured by [XXXXXXXXXX]. The unit was commissioned in [19XX]. The present unit trip frequency is set to [58.5 hertz and 61.5 hertz]. Although the unit is rated at [500 MW], it has been operated at 80% load to 90% load throughout most of its operating life. The steam turbine rotor has a single shaft design with [state number] high-pressure (HP) stages, [state number] intermediate-pressure (IP) stages, and [state number] low-pressure (LP) stages. The last stage (L-0) blade is [36"] long. The L-1 blade is designed with a tangential entry three-hook dovetail inserted on the disk by means of a notch. The blades are made of a 12% chromium alloy steel material of the composition and properties conventionally used in steam turbine manufacture. There are [150] buckets in the present L-0 stage with buckets arranged in groups of [five] for a total of [30] groups joined together by a cover band and a loose tie wire. The airfoil section is enlarged at the tie-wire location. The leading edge of the airfoil above the tie wire is flame hardened to reduce water droplet erosion damage. Operating in the Wilson Line, the L-1 blades are subjected to a wet/dry steam environment.

3.2 SIGNIFICANT ISSUES WITH THE PRESENT ROW

In 2000, the unit experienced high vibration and was taken out of service for inspection. It was found that a single L-1 stage airfoil was separated at the tie-wire hole. In addition, inspection revealed seven cracked airfoils at the tie-wire hole. To avoid such a failure in the future, the first four resonant modes should provide a minimum of a 10 hertz margin from the nearest resonant frequency. The erosion shield shall be located on the bucket in a manner to preclude failure from the first four resonant frequency modes.

4. TECHNICAL CRITERIA

4.1 GENERAL INFORMATION, CODES, AND STANDARDS

1. Upon agreement (verbally or in writing) of intent to purchase a row of buckets, either a sample bucket of the modified design or information describing details of the geometry of the bucket shall be provided by the supplier. This is to allow an independent examination of bucket stresses and resonant frequency modes.
2. Final authorization to purchase the [L-1] row shall be received after the independent analysis has been performed, results discussed, and issues resolved with the selected supplier.
3. The latest edition of the codes and standards listed in Section 5, "References," shall be used to establish acceptable criteria that govern the manufacture and installation of the [L-1] row.

4.2 BUCKET MATERIALS

1. The bucket shall be manufactured from stainless steel equivalent in composition and mechanical properties to those of AISI 403 stainless steel. Other bucket materials will be considered for the bucket if they have superior properties for the environment in which the [L-1] bucket row operates. Covers and tie wires shall be made of AISI 403, AISI 410, AISI 630, or Ti6Al4V titanium alloy materials. Cross-keys shall be made of ASTM A193 Grade material.
2. If buckets are to be forged, they shall be made according to ASTM A314 and heat treated in accordance with ASME A473-80a. If the bucket is to be made of bar stock, the bar stock shall be made according to ASTM A276.
3. Erosion shields shall be made of Stellite 6B material and attached in a manner such that they do not become loose or detach during operation. After fitting, no cavities or hideouts are to be allowed into which corrosive materials may migrate, either during operation or on gear.
4. Test certificates shall be provided for all bucket and attachment parts noted above and shall include material mechanical and chemical properties. Heat treatment charts shall also be supplied if requested.

4.3 PART NUMBERING

1. ~~Brand marks or numbers~~ shall be stamped on the bucket so that the particular melt from which the bucket was made can be identified, and subsequent actions or inspections can be referenced to specific parts. This number shall also be supplied on the moment weight chart.
2. It is preferred for this number/code to be stamped on the exhaust side of the bucket ~~or at a location where it can be seen after installation on the rotor.~~

Example of a Turbine Bucket RFQ

4.4 EROSION SHIELDS

1. Erosion shields shall extend down the inlet edge a sufficient length to protect the admission edge from erosion, shall contain no residual stress or stress-sensitive areas that are likely to cause cracks, and shall preserve the aerodynamic form of the bucket.
2. If a brazing process is used, the thickness of the filler strip between the shield and parent material of the airfoil shall not exceed 0.002–0.004" in thickness.
3. The shield shall be sized so that a resonant frequency node point at operating speed does not coincide with the lower end of the erosion shield.
4. X-ray, impact, and/or bend tests shall be performed to test the quality of the shield application. Results will be recorded and reported by part number.
5. Any buckets that are tested and show regions under the erosion shield where there has not been proper fusion will be replaced at no cost.

4.5 SHOT PEENING/SURFACE FINISHES

1. All buckets will be free from deterioration classified as cracks, dents, nicks, missing metal, or corrosion.
2. The final finish achieved in all root fillets will be 64 microinches or better.
3. The final finish on the airfoils of the buckets shall be in the main direction of the steam flow and shall fall within ± 70 –80 microinches or better.
4. If shot peening or bucket coating is performed, the supplier shall specify the regions where it is to be applied, the procedure by which it is to be performed, and the standard by which it is to be qualified.
5. Any third-party suppliers who are to perform the above work shall be identified along with QA/QC requirements that the supplier will use to ensure that the work is done properly.

4.6 MANUFACTURING CRITERIA

1. Buckets will be checked and verified by the supplier to ensure that the correct radial alignment and pitch is achieved when they are installed on the disk.
2. If required, tie-wire alignment shall be checked and verified by the supplier to ensure that the holes are aligned to within the supplier's acceptable tolerances.
3. Contour profiles shall be checked and verified after the installation of an erosion shield to ensure that any warping or twist is within acceptable supplier standards.

4. Bucket airfoils shall not be welded or hot/cold straightened without written agreement. Any part resized or reworked during manufacturing will be identified by part number and reported as such.

5. Any buckets that cannot be made to reasonably conform to the supplier's standard alignment standards shall be replaced at no cost.

4.7 ROOT AND COVER ATTACHMENT TOLERANCES

1. After manufacture, all pairs of hooks on the root attachment will be properly sized so that the bearing surfaces will match and come into full contact with the counterpart surfaces of the disk hooks during operation.

2. Roots will be properly sized so that no gap exceeding 0.002 inches is allowed to exist between adjacent bearing surfaces prior to unit startup.

3. Sufficient material will be provided to form the tenon head in a manner that will allow the cover band to be fastened tightly to the tip platform such that gaps under the cover band do not exceed 0.005 inches on the inlet edge or 0.003 inches on the discharge side.

4. If an interlocking, integral cover design is involved, the supplier will state the minimum and maximum interference gap size that is allowed between adjacent covers after installation on the disk.

4.8 FREQUENCY TESTING

1. Bucket frequencies will be measured in a room temperature environment. Each bucket shall be securely clamped along the pressure and suction side of the platform. The clamping system itself shall be of sufficient mass to provide a rigid, dynamically inert fixture.

2. The first and second modes of each blade will fall within $\pm 2\%$ of the mean target frequencies, to be identified by the supplier prior to testing. The third and fourth modes of each blade will fall within $\pm 5\%$ of the mean target frequencies.

3. Results of the frequency tests will be referenced and reported by part number. The same information shall be supplied for all spare buckets.

4. Any bucket that fails to fall within the specified range of acceptable frequencies will either be reworked or replaced at no cost to the buyer.

5. A part number will identify any bucket that is reworked to achieve the required frequencies, and details of the work performed will be reported.

6. Results of on-site frequency tests (if required) shall be provided to the plant along with the acceptance criteria for such tests.

7. Upon issuance of a letter of intent to purchase the [L-1] bucket row, the selected manufacturer shall supply a copy of Campbell diagrams from telemetry tests conducted on the L-1 bucket.

Example of a Turbine Bucket RFQ

4.9 MOMENT WEIGHING

1. After frequency testing, each bucket will be individually moment weighed to establish the arrangement around the rotor that will minimize the out-of-balance forces and field balance adjustments required on the rotor.
2. A moment weight chart shall be supplied for the bucket row and shall include the bucket number, order of assembly, and the moment weight for each bucket being installed with the unit of measure for the moment weight being specified.
3. The same information shall be supplied for all spare buckets.

4.10 SHIPPING OF PARTS

1. Selection of a carrier and arrangements for the shipping of parts will be the responsibility of the supplier. Shipping costs will be in accordance with the contracted price.
2. The supplier will be responsible for replacing any parts lost, stolen, or damaged during the course of shipping parts to the plant.
3. A part number listing and other information required to order the supplied parts shall be provided for the [L-1] bucket row, the individual buckets, and assembly components.
4. A list of units, contact names, and telephone numbers shall also be supplied where such parts are interchangeable.

4.11 PRE-OUTAGE PLANNING SUPPORT AND COORDINATION

1. All drawings necessary to support field installation of the row shall be supplied as part of the order.
2. A list of tools, equipment, personnel, and technical support required by the supplier to disassemble/reassemble the unit, remove old buckets, prepare the wheel for new buckets, install new buckets, and slow-speed/high-speed balance the rotor will be supplied as part of the order.
3. A listing of plant support requirements will also be provided.
4. A checklist or sign-off sheet of inspections and tests to be conducted during bucket removal, wheel inspection and cleaning, bucket assembly, unit assembly and slow-speed/high-speed balance of the rotor shall be provided with the quotation no later than two weeks prior to when work is to begin on-site.
5. Upon arrival on-site, each checklist will be reviewed to verify specific support required of the plant personnel identified by the supplier to complete the activity in accordance with the supplier's schedule.

4.12 REMOVAL OF ORIGINAL ROW

1. Prior to removal of the original parts, notable signs of damage or wear to the L-1 disks will be identified, recorded, and verified with the plant manager.
2. Upon removal of the original parts, the disk will be cleaned and inspected for any signs of noticeable fatigue, damage or wear. Results of the inspection will be recorded and verified with the plant with recommendations for corrective action, if any, to be immediately provided.

4.13 PREPARATION OF DISK AND INSTALLATION OF NEW ROW

1. Upon completion of the preparation work, results will be recorded and verified with the plant.
2. During installation, checks will be performed to ensure that the roots are properly sized to ensure proper mating between buckets and disk attachments.
3. The row of buckets will be inserted in a way that ensures that adjacent surfaces of the tangential entry roots will achieve a firm and tight interference fit with their counterparts during the process of installation. A tight ring will be in place before the notch blade is installed. The interference drive of the installed row shall be provided as part of any checklist.
4. If a tenon-cover arrangement is used, inspection will ensure that no discontinuities or surface tears are present in the filet radii where the tenon joins the main profile of the airfoil.
5. The individual bucket number will identify any buckets that required bearing surfaces to be machined or resized to meet the specified criteria, and the work performed will be noted.
6. Upon completion of the installation work, results will be recorded on all checklists and provided to the plant.

4.14 INSPECTION OF A NEW ROW

1. If a tenon-cover arrangement is used, the tenon head will have no steps or indentations on its surface after peening.
2. If an interlocking, integral cover design is used, the supplier shall measure and record the interference gap size(s) between adjacent covers after installation on the disk. All gaps will be within specified tolerances.
3. Upon completion of the installation work, results of the final inspection of the row will be recorded and provided to the plant.

Example of a Turbine Bucket RFQ

4.15 BALANCING

1. The rotor shall be slow-speed balanced in accordance with standard procedures required for the type of balance machine being used.
2. The rotor shall be slow-speed balanced using the factory balance planes. If the factory balance planes are not available, use of field balance planes is acceptable.
3. The rotor shall be slow-speed balanced so that the residual balance in each plane does not exceed a value to be determined in advance by the supplier and verified with the plant. The lowest possible slow-speed balance vibration level is the plant's expectation to ensure minimum vibration during unit startup and operation.
4. When proper slow-speed balancing is complete, proper balance weights (AISI 410 material type) will be installed.
5. Documentation will be supplied to the plant after the slow-speed balancing of the rotor. This documentation will verify that the balancing requirements were met and that the equipment used was sufficiently calibrated to perform the balancing procedure.
6. The rotor shall be high-speed balanced during startup and subsequent unit operation so as not to exceed 3 mils vibration amplitude at running speed and throughout the load range.

5. REFERENCES

- | | |
|-------------------------|---|
| ASTM A276 | Standard Specification for Stainless Steel Bars and Shapes |
| ASTM A314-97 | Standard Specification for Stainless Steel Billets and Bars for Forgings |
| ASTM A370-97a | Standard Test Methods and Definitions for Mechanical Testing of Steel Products |
| ASTM A473-01 | Standard Specification for Stainless Steel Forgings |
| ASTM
A484/484M-00 | Standard Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings |
| ASTM A582/
A582M-95b | Standard Specification for Free Machining Stainless Steel Bars |
| ASTM A751-96 | Standard Methods, Practices, and Terminology for Chemical Analysis of Steel Products |
| ASTM E353 | Standard Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys |
| ASTM E381-01 | Standard Method of Microetch Testing Steel Bars, Billets, Blooms, and Forgings |

Code

Example of a Turbine Bucket RFQ

ATTACHMENTS

Part 1- Costs and Conditions of Purchase

Part 2 – Schedule and Documentation

Part 3 – Acceptance Criteria

The following checklists provide a summary of the key issues/items identified within each part of the bid package. After a bid has been accepted, the checklists are intended to act as control documents, recording the plant's formal acknowledgement that the supplier has complied with the conditions accepted with the bid.

PART 1: COST AND GENERAL TERMS/CONDITIONS

Please complete the following form. Additional terms or conditions should be attached.

1 Cost Breakdown		Prices in US Dollars	
a.	Manufacturing [state number] buckets and all attachment hardware	\$	
b.	Manufacturing [state number] spare buckets with all necessary hardware	\$	
c.	Shipping to plant in [state location]	\$	
d.	Disassembling/reassembling as required for bucket removal	\$	
e.	Installing row	\$	
f.	Slow-speed balancing after row is installed	\$	
g.	High-speed balancing during startup and subsequent operation	\$	
h.	Additional costs: Itemize	\$	
Total			
i.	Bonus/penalty for early delivery	\$	
j.	Bonus/penalty for early installation of buckets and unit startup	\$	
Total		\$	
2 Warranty		Yes	No
a.	5 years, 40,000 hours, or 1000 start-stop cycles (whichever comes first)		
b.	All liquidated damages from shipment, delivery through installation		
c.	Replacement of any bucket that fails to meet technical acceptance criteria		
If no to any of the above, reference item number and state exception:			
3 Minimum Acceptance Criteria		Yes	No
a.	Modified design is to be supplied.		
b.	New row is to be compatible with stationary nozzles and components.		
c.	Design includes an erosion shield.		
d.	First four modes of vibration maintain 10-hertz margin from resonance.		
If no to any of the above, state exceptions:			
4 Other Features		Yes	No
a.	Will the new design provide an efficiency improvement?		
	- If so, indicate what % improvement might be expected.		%
b.	Is shot peening to be performed?		

Example of a Turbine Bucket RFQ

PART 2: SCHEDULE OF DELIVERABLES AND DOCUMENTATION

Using the following list of milestones, please indicate when to expect each could be completed.

Week	Schedule for Manufacture, Delivery, and Installation	Documentation to Be Supplied
1	a. Placement of order	Sample bucket or details of bucket geometry.
	b. Selection and testing of forging or bar stock materials	Certificate of material mechanical and chemical properties.
	c. Manufacture of buckets and attachment parts	Part number listing.
	d. Application and inspection of erosion shields	QC procedure used and results referenced by part number.
	e. Shot peening/coating/surface finishing of parts	QC process used for shot peening.
	f. Radial alignment and hole position checks of buckets	Identification of any part (by number) resized or reworked.
	g. Final inspection of row (buckets and assembly parts)	QA/QC procedures used and results of inspection for each part.
	h. Frequency testing of individual buckets	Test procedure used and frequencies referenced by part number.
	i. Moment weighing	List of moment weights and moment assembly chart.
	j. Shipment of row to site	Selected carrier. Date of shipping. List of parts sent/received.
	k. Shipment of tools to site	Checklist of tools/equipment provided and those supplied by plant.
	l. Disassembly of unit and removal of original L-1 row	Checklist of tests and inspections. Disk condition before and after.
	m. Preparation of disk for new row	Checklist of tests and inspections. Report on final actions performed.
	n. Installation of new row	Checklist of tests and inspections. Report on final actions performed.
	o. Inspection of new row	NDE test procedure. Report on results of tests.
	p. Slow-speed balance of new row and assembly of unit	Balancing procedure. Results compared to agreed-upon criteria.
	q. High-speed balance of unit during startup and operation	Balancing procedure. Results compared to agreed-upon criteria.
	r. Removal of equipment	Final report on status of rotor.

Supplier Attachments to Part 2: The following documentation should be attached to Part 2 as part of the bid package:

1. Itemized checklist of activities that supplier will perform to remove the existing row
2. Itemized checklist of tests and inspections that supplier will use to inspect and prepare the disk
3. Itemized checklist of tests and inspections that supplier will use to assemble and QC the new row
4. Itemized checklist of tests and inspections that supplier will use to slow-speed balance the rotor with the new row

For each activity – removal, preparation, installation, inspection, and balancing, supplier should identify technical support required of plant.

PART 3: CHECKLIST SUMMARIZING COMPLIANCE WITH ACCEPTANCE CRITERIA

The following presents a checklist of requirements and acceptance criteria identified in Section 4 of the RFQ. Suppliers are requested to indicate compliance or non-compliance with these requirements. Conditional changes should be referenced and presented as an attached page to this checklist.

Compliance			Requirement – [Details Presented in Section 4]
Yes	No		
		1	Provide a sample bucket or supply the geometry for an independent examination. (Indicate which.)
		2	Buckets are to be manufactured from AISI 403 stainless steel. (If other, indicate material.) Erosion shields are to be manufactured from Stellite 6B material. Provide test certificates to show conformance of material and chemical properties.
		3	Parts are to be individually numbered for reference.
		4	Erosion shields shall contain no residual stress and preserve the aerodynamic shape of the airfoil. If brazed, the filler strip shall not exceed 0.002" to 0.004" in thickness. Resonant frequency node points of fundamental modes are not to occur at the end of the shield. Erosion shields are to be tested for proper fusion.
		5	Shot peening/coating is to be performed. (Identify where.) Final finish of all root fillet radii will achieve a 64-microinch surface or better. Final finish of airfoil surfaces will achieve 70-80 microinches or better.
		6	Radial alignment and pitch are to be checked and shown to be within allowable limits set by the supplier. Tie wire hole alignment is to be checked and shown to be within the criteria set by the supplier. Warping from erosion shields is to be checked and shown to be within allowable limits set by the supplier. No airfoil shall be welded or straightened without written agreement of the buyer.
		7	Roots will be properly sized to conform with disk attachments so that no gap exceeds 0.002".
		8	Gaps under a cover band will not exceed 0.005" on the inlet edge or 0.003 inches on the discharge edge. If an integral cover is used, the supplier will state the maximum and minimum allowable gaps at zero rpm.
		9	Bucket 1 st and 2 nd modal frequencies will fall within ± 2% of the mean specified by the supplier. Bucket 3 rd and 4 th modal frequencies will fall within ± 5% of the mean specified by the supplier. Provide the results from on-site frequency tests if required. Provide the results of telemetry tests performed in a spin pit or from another plant site.
		10	Buckets will be moment weighed and chartered for installation to minimize out-of-balance forces.
		11	Provide a part number listing and other information required to ordered supplied parts.
		12	Provide drawings necessary to support field installation of the row. Provide a checklist of tools, equipment, and technical support in advance of all site work. Provide a checklist of tests and inspections to be performed during bucket removal, wheel cleaning and inspection, bucket assembly, and slow-speed balancing of the rotor.
		13	Provide the plant with a report of damage or wear to the L-1 disk before and after removing the buckets.
		14	During insertion, the procedure used will maintain a tight interference fit between adjacent buckets. A tight ring of buckets will be in place before the insertion of the notch bucket. The thickness of the notch bucket will be recorded and supplied to the plant.
		15	Inspection will ensure that no tenon heads have steps or indentations on their surface. If an integral shroud is used, all gaps between adjacent covers will be checked, recorded, and supplied to the plant along with the acceptance criteria.
		16	Balance the rotor and install proper weights. "As left" vibration amplitudes and phase angles along with slow-speed ounce-inch unbalance at each plane are to be reported and verified with the plant.

LSB Replacement - Bid proposal Eval. ①

GE.

4 options P4 - depending on pin removal < 5% stuck & refurb bKts on 2nd unit costs - no cost for refurb

+ torsional tendencies - see 3.4

• Schedule - commitment by Oct 29

p-1 [• continuously coupled covers -
• articulated sub-sleeve lower mid range connection
Bucket Suppressor/dampening

SSR Torsional - None - no effect

P4

- GE no torsional vib model

Benefit - original manufacture draws - risk of assembly part fit-up probs.

- Spares yes - (6/job) 6 total

ABC pin pushing

+ (2 shifts for training)

+ training - time & material basis

- more customer responsibilities for Bore & shroud array

Risk Assessment & mitigation study?

②

10/17

3.5

Is this included in price

- update feasibility study $\sim 10\%$ flow increase
- preliminary turbine cycle for operation at increased flow

Additional testing/evaluation ^{from} BAPT - is this
included. TIL 1206

Steam Turbine Coperate Study

New
Bath
units

✓ A - 14,504,000

✓ B - 14,998,000

C - 12,701,000

D - 12,995,000

- bucket removed by milling

- new uz , refurb 41

- 11 11 11 cl milling

PS1 - Schedule 4-1 PS1

Payment Schedule 4.2 - Termination

PS4

53

- 2 guided damage - PK

Bonus $30 - 2 = 28$ days @ $10K/hr$ + 10%

~~Schedule~~ / Blash cleaning & mag particle prior to turning rotor over

Blank clean & NDT L-O Love bail

GEZ 4982 B - Steam Turbine

Quality System

Stuck pin removal

GE

$\$240/\text{hr} \times 2.5 \text{ hrs drilling/pin}$

$= \$480/\text{pin}$

$\$600/\text{pin}$

P&F build

NN30

~~stg share~~

stg ref

Bude MM

PROCESS

Toshiba

From Chris 10/22/09

→ torsional $\$16,500$

→ boreasanic $\$12,000/\text{rotor}$

→ phased array $\$15,000/\text{rotor}$

$2 \text{ hrs/pin} \times 2500/\text{shift}$

→ 10 hr/shift.

$5 \text{ pins/shift} \times \$50/\text{pin}$

IG509-03

Do not include - Septum study, SAA
adjust their original bid
diameter study
to

U1-C @ air leakage 16 CFM
GSB Heat exchanger BSV-396

9255 - ZSGA - M2064A E

Toshiba - max penalty

$$5\% \times 9,994 e^6 = 499,700 / 2,000 / \text{hour} \\ \approx 30 + 5.2 = 35.2 \text{ days}$$

GE max penalty

$$10\% \times 14,196,553 = \frac{1,419,655}{10,000 \text{ hr}} \\ = 1.5 \text{ days}$$

~~unsub. case # 44 Coleman's corner~~

~~'John Coleman'~~
Re

Total

4,995,500

Paperline Bourgeois ~~6/15/2015~~

12-15

for 5' anal

6/12-15 ~~15~~ order

\$2,000/hr

Contract award letter PDF

Sample

Fracture mechanics analysis

Toshiba - 10/1/9

NDE - Westinghouse
- Rinehartd) open for negotiation

Darrell Hoffman -

Jeff Wenzel - Regency - labor equipment
Akroyd - value rebuilds.
2/3 Gen repair
1/2 turbine

* Splitting 15th stage creates alignment problem

- PTA - Skellite robotic welding/coating
- Lateral Torsional FEA models

Noriaki -

grouped blades

(7) on CCB

material outside Toshiba specs - reason for
blade tip failure.

* TGT joint venture w GB yokohama

cover segment fence holes.

forgings - US or China

Toshiba

paper - pore inspection analyze old data
w/ today's analytical programs.

→ Regence-

materials & analysis group Conditions
alternant

* Can do this -

fracture mechanics - worst case assume
defect smaller than detected & do
fracture mechanics on it for
life assessment.

[Forward Sonic ~~planned~~ array to
Regence.

TIL

9/29/9 GE Bid Review mtg.

Low Ecnasick - Atlanta Atlanta

Mark ? - UK (TBL)

Adam Holawinski -

Richard Pinko - torsional interaction -

- similar new EBW buckets / existing buckets

Stuck pins - drilling or ~~EBW~~ EDM, milling.

Torsional - resbe. included in cost?

• Set up lathes for Rotor bore inspections

• Bucket refurb - 30 yr UK. Slides

• inconnel weld hip attachment

• x ray for weld imp.

• hard face weld leading edge

buckets

changes

costs

frequency + mode shape

gain on protection

Mitigation - HVDC controls
add damping

• protection - SMF relay

• hard pass filters

- Torsional

• stress

• delay

GIB Review.

②

(TIL 1206 - implications of operating at increased steam flow.)

• proposed in contract. to check everything

• Lathe.

MIDA - Review 9/25/09 08:00

W - Bob Allen Sales

- ① Price Breakdown? NOE - will provide
- ② Not providing spare buckets - Negotiable.
- ③ NDT - Lathes/stands for rotors - required for bore insp
What about bucket replacement?
- ④ Payment - negotiable
- ⑤ - NO 30" LSB installs? 52 & 102 US / Japanese
- ⑥ Bonus? → Negotiable -
- ⑦ EBW Attachment? p 104
- ⑧ - Campbell drag - ? p 99, 100 difference
- ⑨ - Hibachi City 90 miles N Tokyo

(2 lathes + 1 set power rollers)

4 - G2's 3 - D8's

* Safety, schedule, cleanliness

Team - New York - 4 Runs CCB's

- Mark Brezland - Stellite installation
Tig/inconel attachment.
weld process.
attaching stellite

MDA

KIDT

2010

2011

\$187,200

192,816

Reinhardt

Spanner = available @ installation/spanner.

Integral conn design tie boss
hub & sleeve
pinned-on side entry sleeve.

→ Analytical torsional study →
Δ frequency

9/23/9

①

Toshiba

?

p2 - what is ADP

TIC - Toshiba International Corp.

p2/3

Schedule definition

p4

Incentive bonus - reverse of liquidated damages

"

Dec 1, 2009 Contract award

see p3

Section 2.2 Tech report for torsional concern
enhanced G2 design, identical root design

{ Integral covered -
Side entry covered - }

3.2 p13 - Racks for holding rotors during repair
who supplies turning lathes

Tab 5

bucket wgt - op data

Experience list - TCAF-30 different from
6F specified bucket
NN30"

Proposed Schedule - Reenco? doing installation
Cold Services

Bladders

② - blast clean ~~rot~~ bucket root areas C-0
will another blast cleaning be required

TBuckets - G0 HZ Design?

* G2 / G3 ~ Supercritical steam turbines

9/12/7 GB mtg.

⑦

* Conf call w John Yeovs * 2.5 yrs Atlanta
Lash sty buckets.

- tip laparoid
- not typical erosion
- long term - (10 yr cycles)
- short term reliability concerns. ok
- acute event for non classical development of erosion
- 30" cent coupled self shielded design 99,00
- grinding for structural

self shielded let Hite material - depth? - base material

- Re-finish damage
- hood sprays - cool buckets @ low load

TFL 1521, 630 GBK 111680

- drop tank tracking of erosion to measure progression of erosion

- Insp. base - high cycle fatigue.

- crack from erosion pit.

* upgrades - not for L-O only. - adding mass increases forces on dovetails.

* check routine removal groove, annular.
important for inspections

(annual inspections)

Section Replacement w modern 34.5 LSB

- o 34.5 LSB
- o new inner casing
- o optimized outer steam guide
- o 2%
- o improved sealing
- o ppt - partial partition replacement
- o Brush seal I.S. pkgs ?? replacing
- o spacer/corrosion

CP
package
lifetime
concerns

2 mils/ft + alignment

10.5" Double layer FR 3 Dacron 30+ year service

Carbon buckets - we have
upgrade to schubert + 2% Stg efficiency

Mark Skovhus does study.

TEL
1206